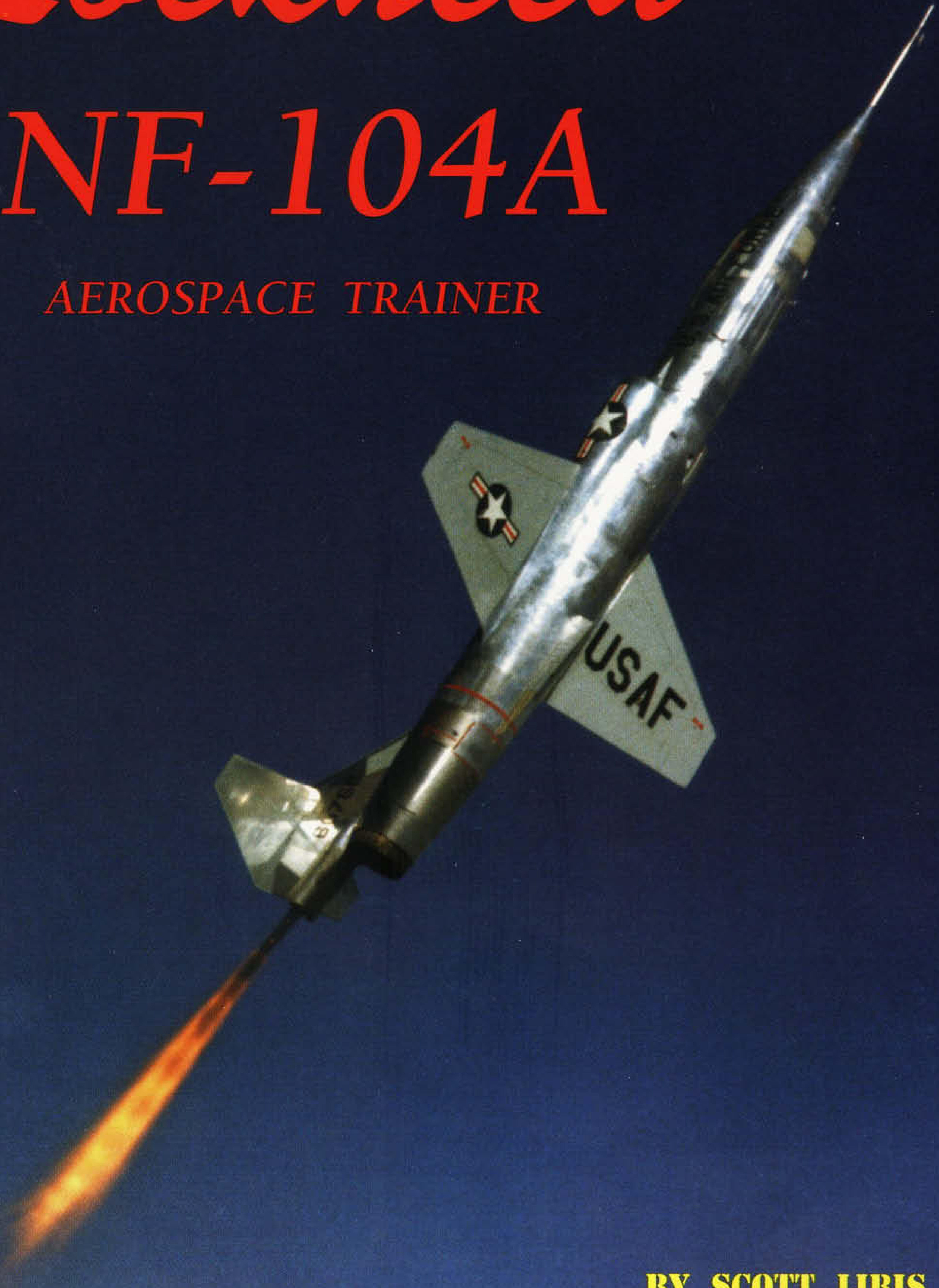
AIR FORCE LEGENDS NUMBER 204

# Lockheed

# NF-104A

## AEROSPACE TRAINER



BY SCOTT LIBIS

PHOTO RESEARCH BY TONY LANDIS

## ABOUT THE AUTHOR

Scott Libis was first exposed to military aviation in 1970, when he toured a near-by Air National Guard Base. The flight line was humming with activity and packed with camouflaged F-100 Super Sabres. Mesmerized by this experience, Scott immediately enlisted in the U.S. Air Force upon graduating from High School. Scott completed his Air Force "hitch" working in aircraft maintenance, then left to go back to school earning a Bachelor of Science degree in Aviation Management. Since then he has worked for Rockwell International and Northrop Grumman, where he tested the B-1B and B-2A bombers. Scott is currently a Quality Engineer residing in Palmdale, California. This is Scotts second book, the first being Air Force Legends Number 201, The Martin XB-51.

## AUTHORS NOTE

Mission design series (MDS) is a brief alphanumeric designation used by the United States Air Force to describe aircraft. In this case, F means fighter and 104 signifies the 104th fighter design to receive a MDS designation. The "N" prefix is most frequently used in the test world and signifies a configuration change. Configuration change, as implied here, means conversion to aerospace trainer.

## CONTRIBUTORS

Robert Archer, Jim Logsdon, Robert Gilliland, George Marrett, Charles Wygant, Bill Flanagan, Marty Isham, Craig Kaston, Rick Koehnen (Twelve Squared) Tony Landis, Lockheed Martin Skunk Works, Denny Lombard, Peter Merlin, Ila Nelson, Doug Nelson, Raymond Puffer, bob Hoey, Tom Newman, Andy Meyer, Bill Meyer, Mick Roth, William Swisher, Joe Wilson, Air Force Flight Test Museum and the Air Force Flight Test Center History Office (AFFTCHO).

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Tony Landis, for photo research.

Anyone having photos or other information on this, or any other naval or marine aircraft, may submit them for possible inclusion in future issues. Any material submitted will become the property of NAVAL FIGHTERS unless prior arrangement is made. Individuals are responsible for security clearance of any material before submission.

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**FRONT COVER**
**NF-104A going vertical at nearly 70° on its way to the fringes of space. (Lockheed via Tony Landis)**

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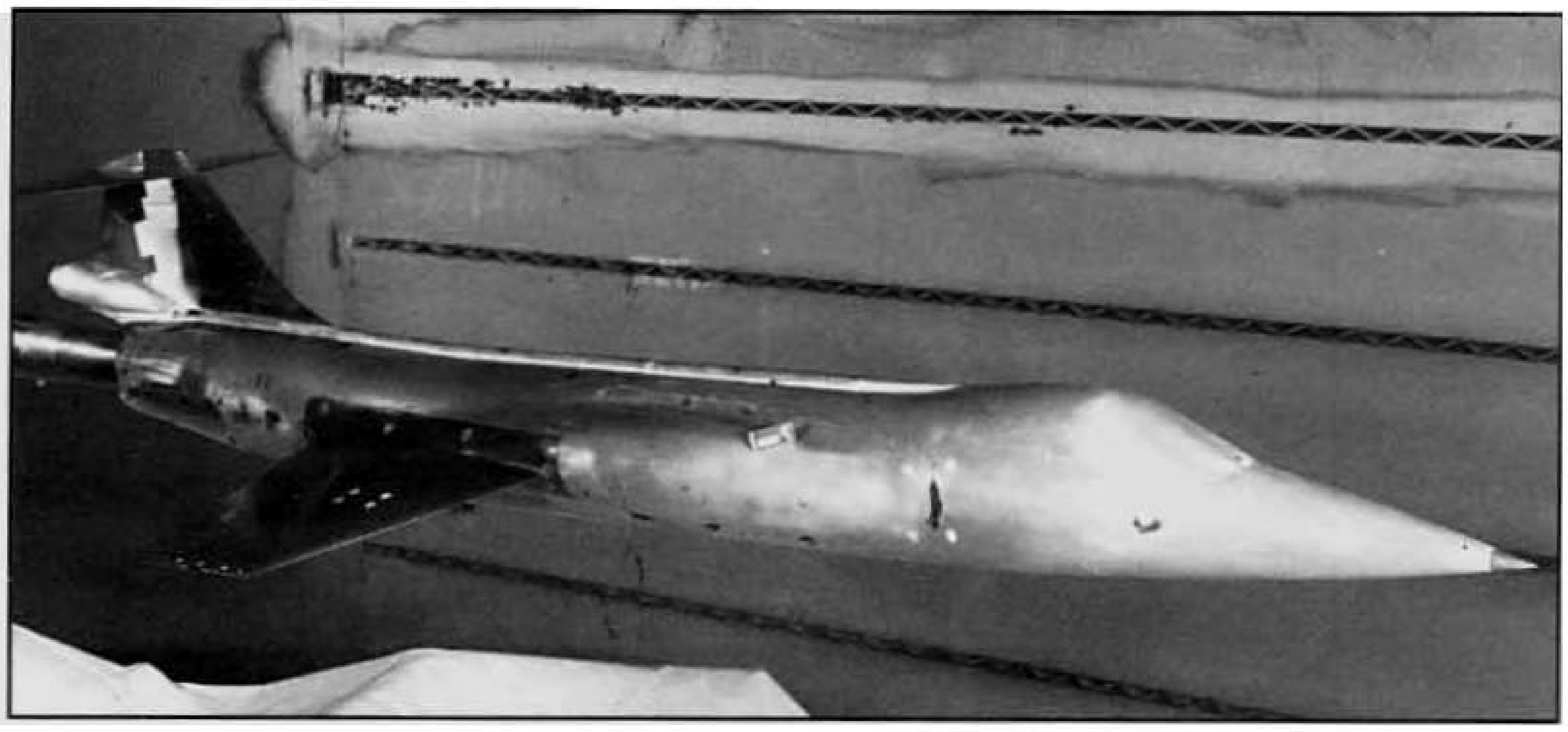
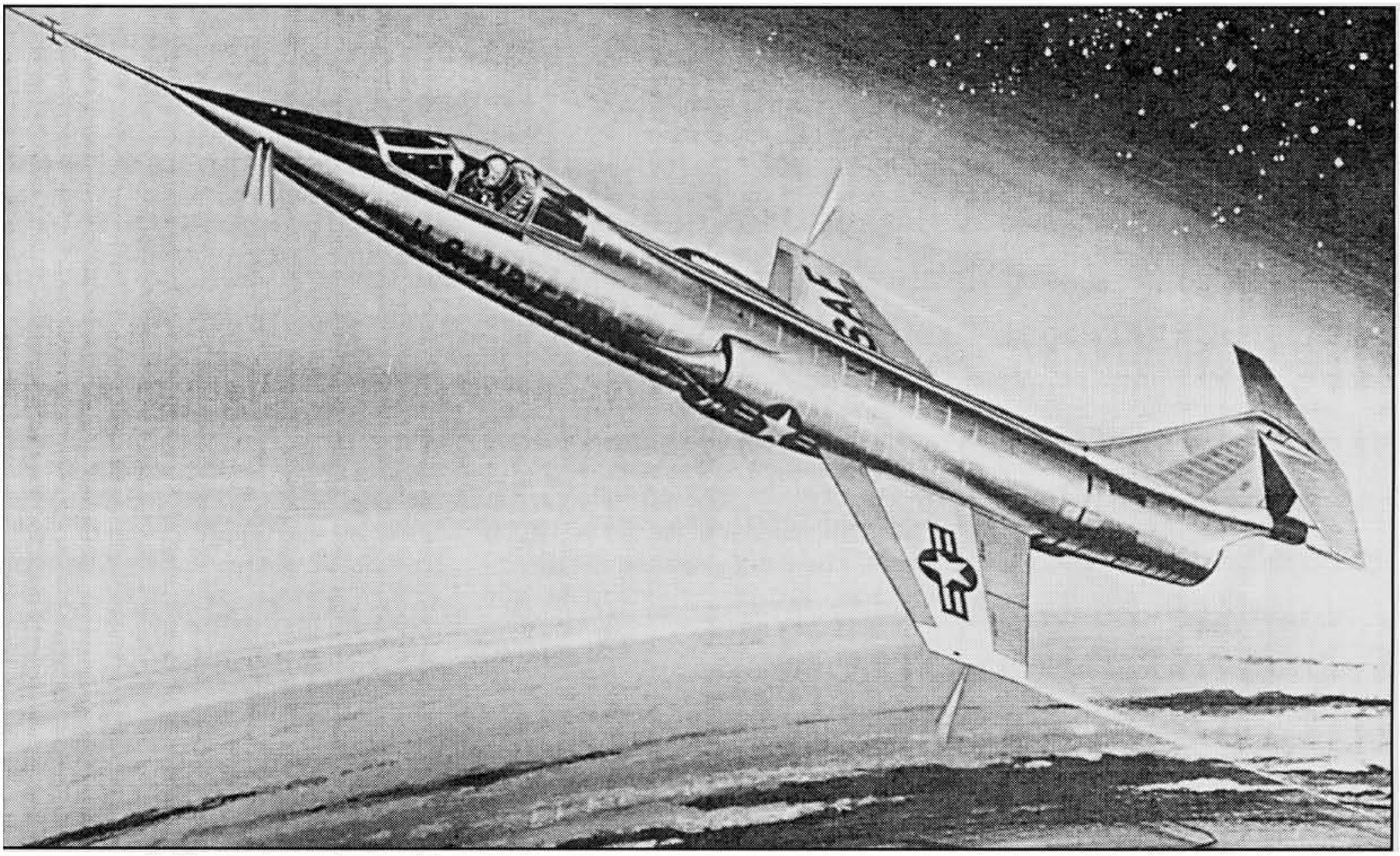
**Below, Lockheed wind tunnel model of the NF-104A. (via Tony Landis)**



# ROCKET POWERED LOCKHEED NF-104A AEROSPACE TRAINER



Above, artist's illustration of the rocket powered NF-104 utilizing its nose and wing tip reation motors to control pitch, yaw, and roll. (via Scott Libis)

## THE MISSILE WITH A MAN IN IT

During the air war in Korea in 1951, the soviet-built MiG-15 fighter startled western observers with a performance advantage over the U.S built F-86 Sabre. The MiG's rate-of-climb and top-end speed were greater than that of the Sabre, which at that time represented America's state-of-the-art in fighter aircraft. This gap in performance against an airplane that was supposed to have been of inferior quality was more than just embarrassing. If it weren't for the superior tactics developed by the U.S. pilots, their Korean/Soviet counterparts would have ruled the skies during the Korean War. Determined not to send their pilots off again to fight under similar circumstances, the Air Force put out the call to industry to rectify the situation. The Mach two F-104 Starfighter was Lockheed's reply to counter the Soviet Union's ever increasing MiG threat.

Speed was the answer. Referred to as "the missile with a man in it", the Starfighter captured World Altitude, Time to Climb and Absolute Speed records. Orders were placed by the U.S. Air Force for 722 F-104s in 1958, and the aircraft became operational soon thereafter. Unfortunately for Lockheed, the Air Force's emphasis shifted to a deep penetration philosophy. Aircraft with greater range and load carrying capabilities would be required. Range and load were not two of the Starfighter's strong points, so the Air Force cut its F-104 order in half and concentrated on aircraft like Republic's F-105 Thunderchief. On the other hand, there were NATO countries that needed a fighter with the qualities that matched those of the Starfighter. In Europe and Asia, potential adversaries were quite often bordering countries, so range was less of a consideration. Speed was of paramount importance and the F-104 was at the right place at the right time. Orders poured in from 14 countries making it an extremely successful export fighter. The F-104 enjoyed a long production run with the final aircraft rolling off the assembly line in 1980.

The sharp looks and high performance of the F-104 came at a price. In order to achieve Mach 2 performance, the wings were designed as small as possible to reduce aerodynamic drag. Razor thin, clipped tapered wings make for great high speed performance, but pay concessions in the range department. Highly loaded wings, such as these, generate less lift, resulting in poor cruise fuel economy. Another disadvantage is a tricky takeoff and landing approach. Stall speed was appallingly high with these small wings. As if this weren't enough, T-tails were in vogue during this period, with many manufacturers selecting them for their designs. Lockheed followed the pack with this feature unaware of the pitchup phenomenon that would ensue. Prior to pitchup, the airplane would lull the pilot into a false sense of security during a steep climb, then without warning, viciously swap ends.

The West German Air Force was Lockheed's biggest customer, buying 917 Starfighters. By 1976, they had lost 178 of these aircraft in accidents. The airplane took on the new nickname, "Widow Maker", further testimony to the unforgiving nature of this airplane. And yet, in spite of a dismal safety record, the airplane prospered.

## AEROSPACE RESEARCH PILOT SCHOOL (ARPS)

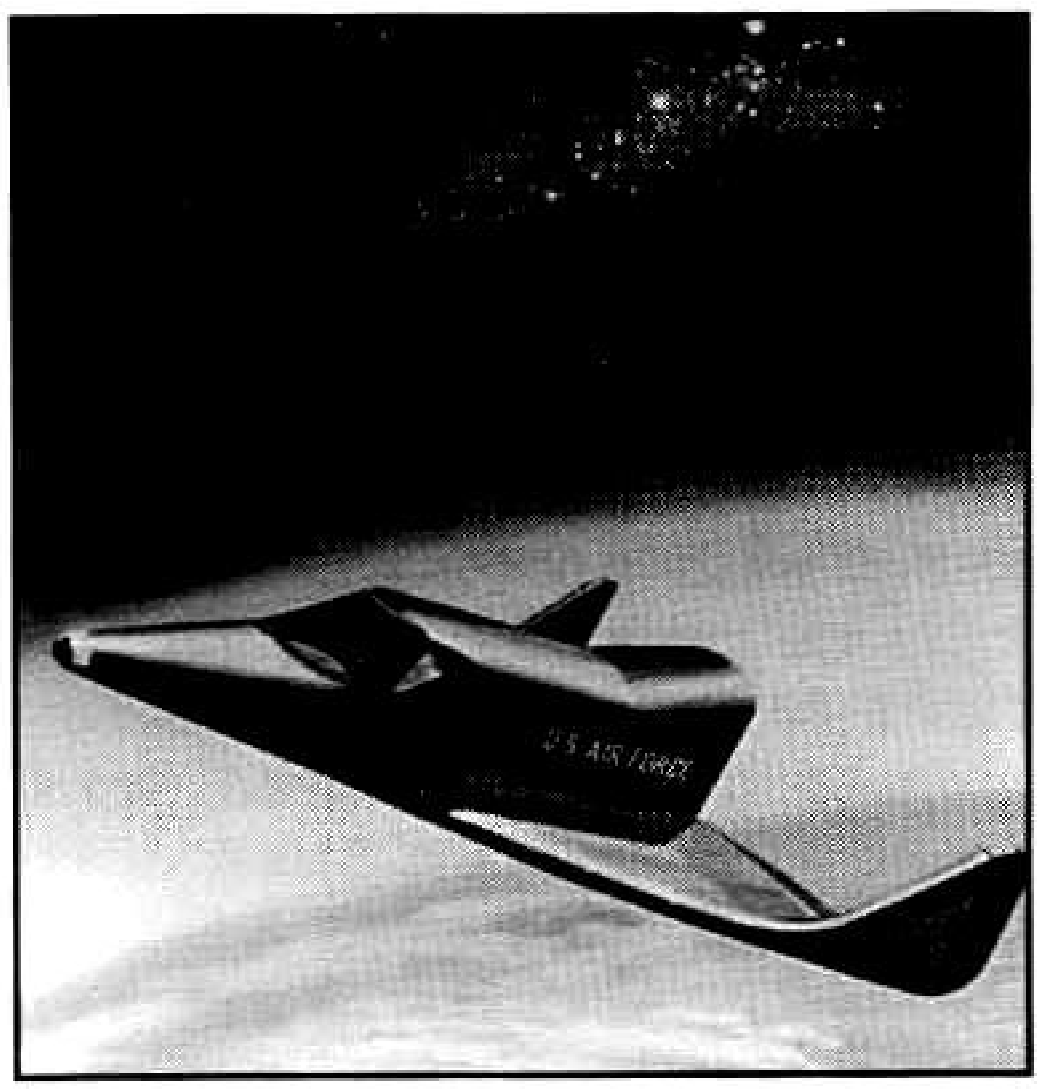
One of the defining events of the 1960's was manned space exploration. The space race with the Soviet Union had spawned numerous manned space research proposals, and it became evident that there would be a critical shortage of qualified candidates to fly them. Seizing this opportunity, the Air Force announced on October 12, 1961, that it was going to re-designate its Experimental Flight Test Pilot's School at Edwards AFB. Renamed the Aerospace Research Pilot's School, this new name reflected the shift in curriculum from training the traditional test pilot, to training pilots to perform manned space research programs. The long familiar test pilot course would be retained by the school and serve as a prerequisite for the eight month aerospace course. ARPS would also admit graduates from the U.S. Navy's Test Pilot School and the Empire Test Pilot School in England.

The school acquired a number of F-104's to familiarize students with the handling qualities of high performance aircraft. Part of the school's curriculum involved a low lift/high drag landing to simulate a lifting reentry vehicle's return from orbit. Space planes on the drawing boards at that time used small, stubby wings, or were lifting bodies with no wings at all. The lift characteristics of these designs would be poor at best and required the development of a specialized energy management landing approach. Already resembling a futuristic space plane, the school's F-104's would be perfect simulators for this new approach and landing.

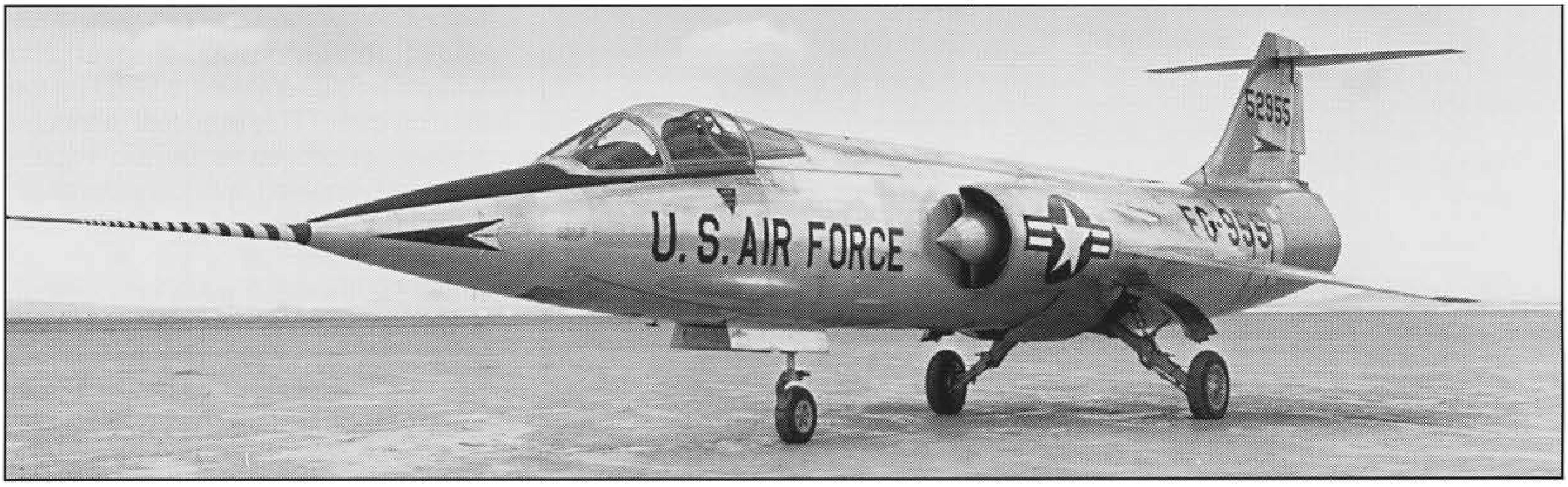
The maneuver started at 12,000 feet, where the aircraft would be dirtied-up, or made as aerodynamically unsound as possible. Flaps would be set to the takeoff position, landing gear lowered and the speed brakes would be extended. A dive angle of 30 degrees would be established with 80 percent power, holding 295 knots straight down to the runway. The pullout would be initiated at 1,500 feet, allowing for little miscalculation on the student's part. A "hic-up " from the aircraft at this point might also spell disaster. In this configuration, the '104 had a lift/drag ratio of about 2.2/1 versus the 17/1 of a commercial airliner. If the student could master this maneuver, he was ready for anything else that the school might dish-out.

These L/D landings mimicked the landing characteristics of the X-15, already well under way at Edwards AFB. The X-15 program was making giant strides in exploring the mechanics of space flight. Jointly sponsored by the Air Force, Navy and NASA, the X-15 explored the viability of boosting a man and payload into a sub-orbit via a winged spaceplane. In order to conserve precious fuel, the X-15 would be carried aloft by a B-52 mothership, reminiscent of earlier rocket plane programs. At altitude, the research plane would be dropped, free to proceed with a full load of fuel. Once launched, the operational envelope of the X-15 included speeds in excess of Mach 6 and altitudes of over 340,000 feet. Propelled to hypersonic speeds, new space age materials would be validated under the intense aerodynamic heating. Confidence gained from these tests reinforced NASA's plans to proceed with Project Mercury.

On the horizon lay the newest and most ambitious project to date for the Air Force. The X-20 Dynasoar (Dynamic Soaring), was to be the Air Force's first space plane capable of carrying a single astronaut and payload into space. The militarization of space seemed to be the next logical step in the evolution of the Air Force. The X-20 was to be boosted into orbit by the newly developed Titan 3 rocket, descendant of the Titan booster used on the Gemini program. Once completed, versions of the Dynasoar would include a manned space bomber, reconnaissance platform and high speed test vehicle. ARPS bore sole responsibility for preparing this next generation of military space pilots.

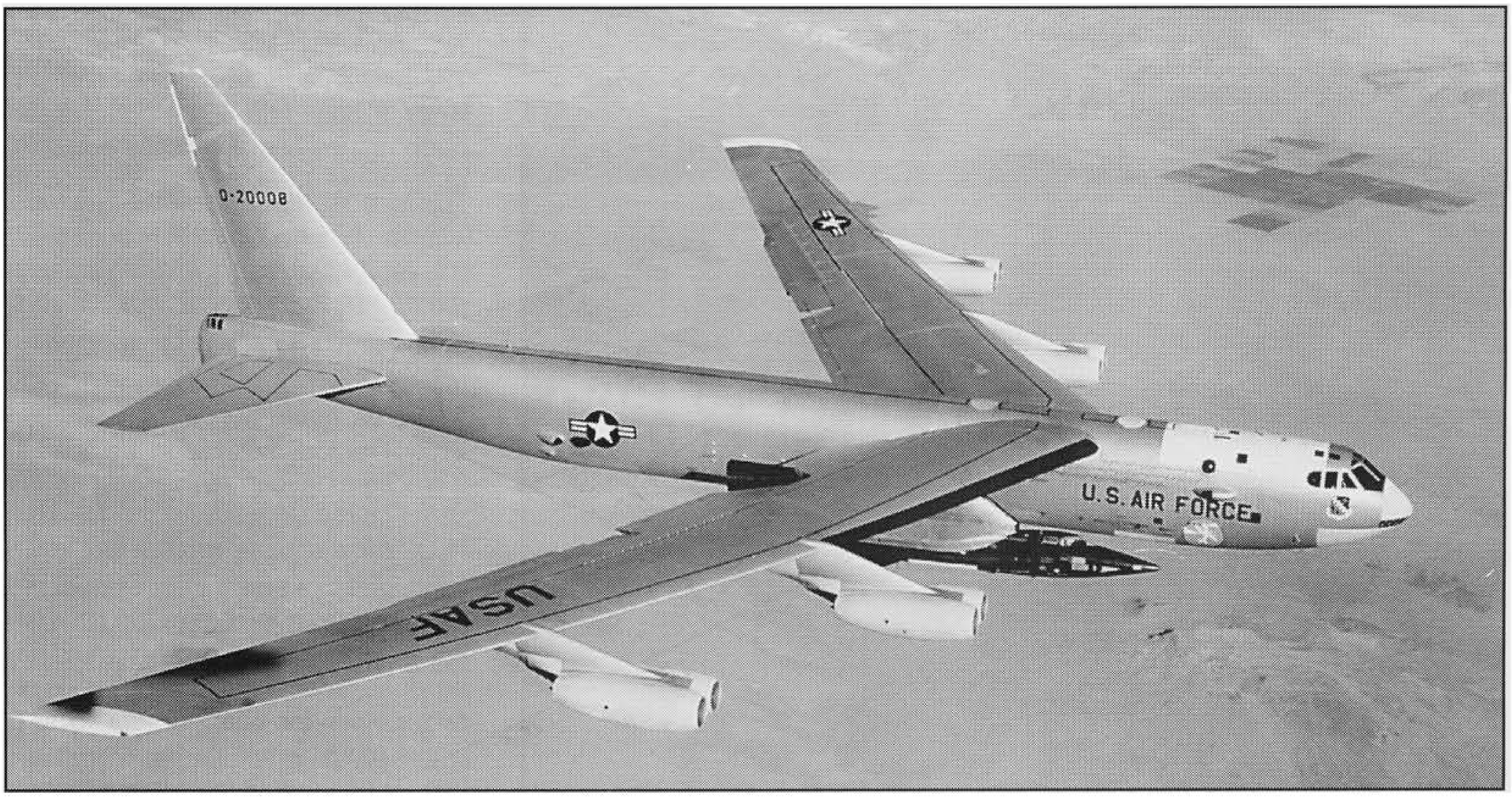


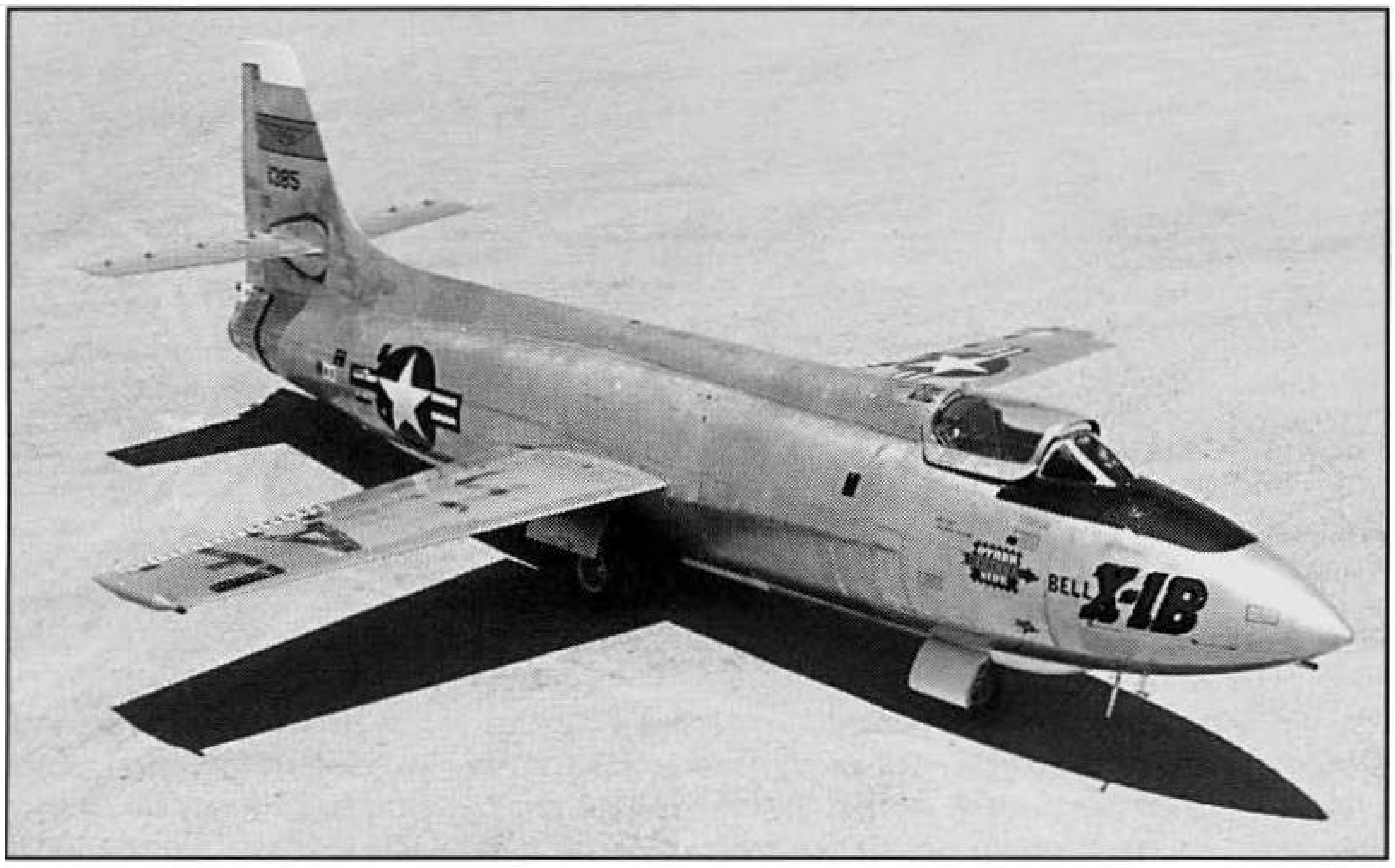
To some, the task of training pilots for this mission seemed insurmountable, due to the lack of trainers specifically tailored for student astronauts. ARPS instructors Major Frank Borman (later to fly Gemini and Apollo missions), Major Robert Buchanan, Lieutenant Colonel Tom McElmurry and Mr. William Schweikhard envisioned a low cost reusable space trainer, possibly derived from an aircraft already in the inventory. The bid went out for just such an aircraft. One proposal from North American Aircraft would use its Proven X-15 with modifications making it more suitable as a



At left, artist's illustration of the X-20 Dynasoar space plane at the edge of space after release from its Titan booster. (via Scott Libis)

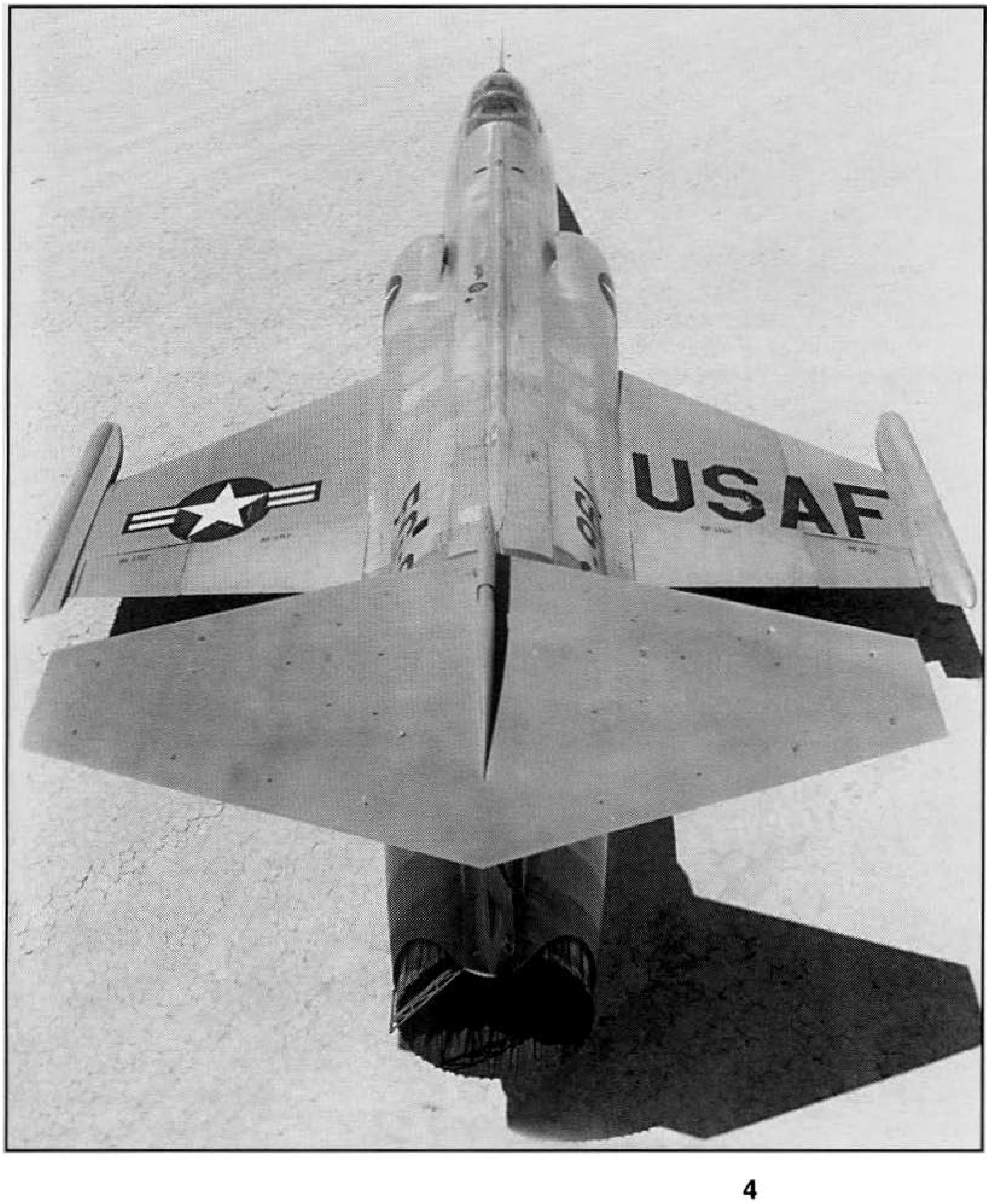
Above, F-104C's wing structure and area approximates that of the X-15 shown below, and therefore was a natural to train potential aerospace pilots for the X-20 and other lifting body programs. Once a rocket motor was added, the F-104 had enough power to simulate X-20's flight profile even though it could not fly as high or as fast as the X-15. Bottom, the X-15 attached to the B-52 dropship. (AFFTC/HO via Scott Libis)





**Above, the X-1B was being used as a Reaction Control System test aircraft when cracks in a fuel tank led to its permanent grounding. (USAF via Tony Landis)**

**Below, NASA 55-2961 with early wing tip self-contained RCS pods, took over the test work from the X-1B in 1959. The wing tip pods controlled roll. (NASA via Tony Landis)**



trainer. A second cockpit would be added for an instructor pilot and wheels would replace the skids on the landing gear. This proposal, although appealing, proved to be too expensive and received little consideration. Lockheed studies of a rocket augmented version of its popular F-104 proved to be much more economical, even though the '104 would not be able to match the X-15's speed and altitude. Lockheed's compromise in performance was acceptable because it offered one thing that the X-15 could not match. It could takeoff and land under its own power, eliminating the need for the costly mothership.

## REACTION CONTROL SYSTEM TEST AIRCRAFT, NASA #961

In 1959, NASA modified a single JF-104 (S/N 55-2961) with a reaction control system borrowed from an earlier X-plane project. The last three flights of the X-1B were dedicated to checking out a rudimentary $H_2O_2$powered reaction control system. This rocket plane was to have provided the then much-needed data on a "flying reaction control system" in preparation for the upcoming X-15 flights. Cracks in a fuel tank led to its permanent grounding, before useful testing of the RCS could begin in earnest. NASA then elected to substitute an F-104 for the sidelined rocket plane. The new century series of jet fighters, which included the F-104, possessed performance characteristics equal to, or greater than, the early rocket planes.

Pods mounted on the wing tips housed a single reaction control motor and enough $H_2O_2$ to provide roll control. Pitch and yaw inputs would be made by the four reaction control motors installed in the nose in a cruciform layout. This would be the same layout selected for the NF-104. $H_2O_2$ for the nose motors would be contained in a tank just forward of the cockpit. However, unlike the NF-104, this reaction control system would not be dual redundant. Instead of using two motors for each control axis, a single motor would perform the function. Thrust output from these motors was proportional, varying with the deflection of the controller handle. This differed greatly from the NF-104's motors which were full-on or off, with no capability of thrust modulation.

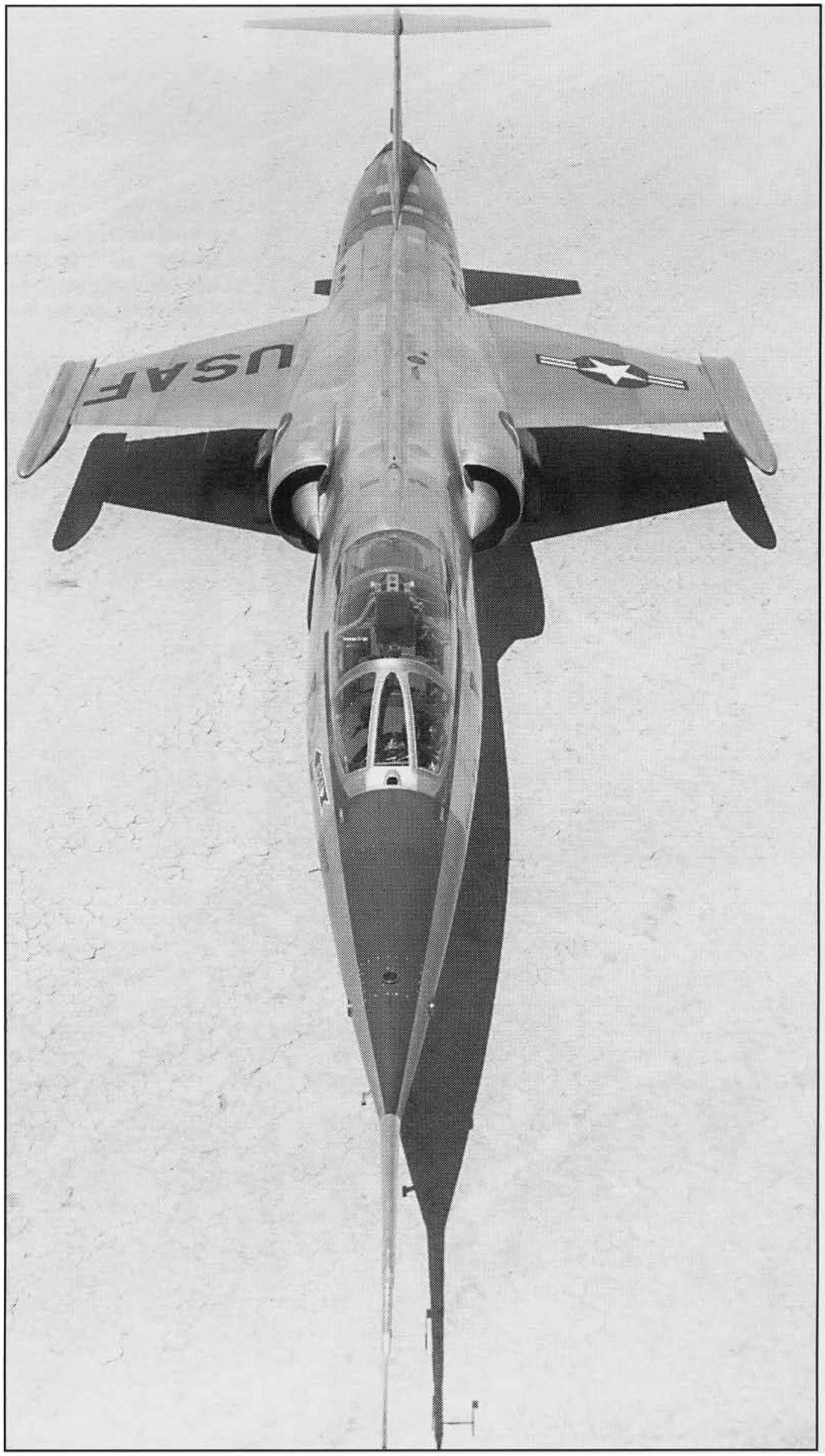
NASA #961, as the aircraft came to be known, flew in this configuration for 28 flights from 1959 to 1961. During this program the aircraft would be subjected to dynamic pressures as low as 6.8 psf. A program Max altitude of 83,000 feet would be recorded on another flight. Initial pilot complaints centered around the cockpit instrument displays crucial for monitoring zoom performance. The angle of attack indicator and the alpha and beta cross-pointers weren't centrally located and the time it took to scan for information increased the difficulty of the piloting task. Pilots Neil Armstrong (first man on the moon), Joe Walker and Robert White flew this aircraft gaining experience flying with an active reaction control system.

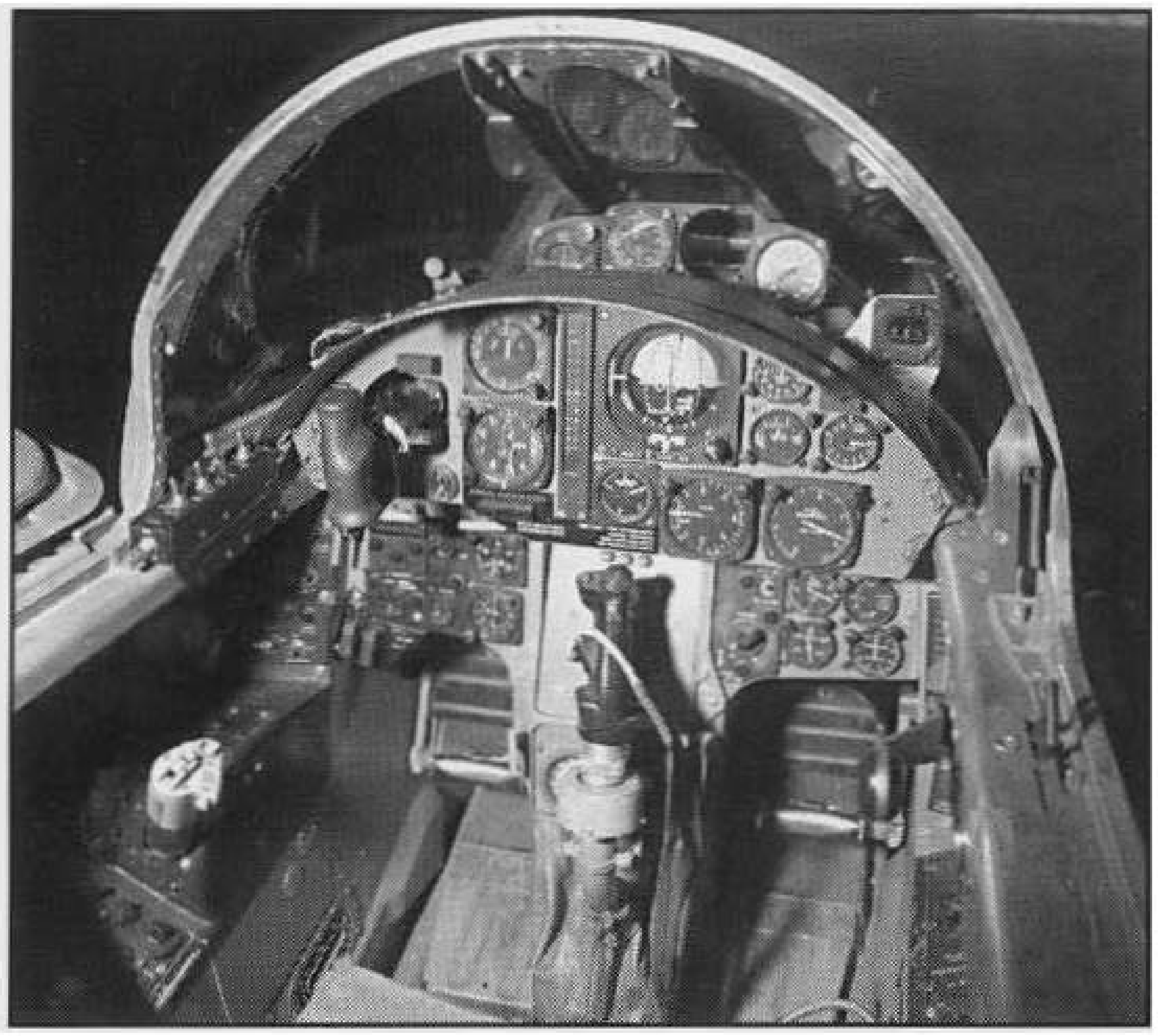
Additionally, an onboard experiment was carried on most flights. The experiment was a dust filter and high altitude air samples were collected. An in-depth analysis was then made of the airborne particles found and any effect they might have on a vehicle traveling at high altitudes.

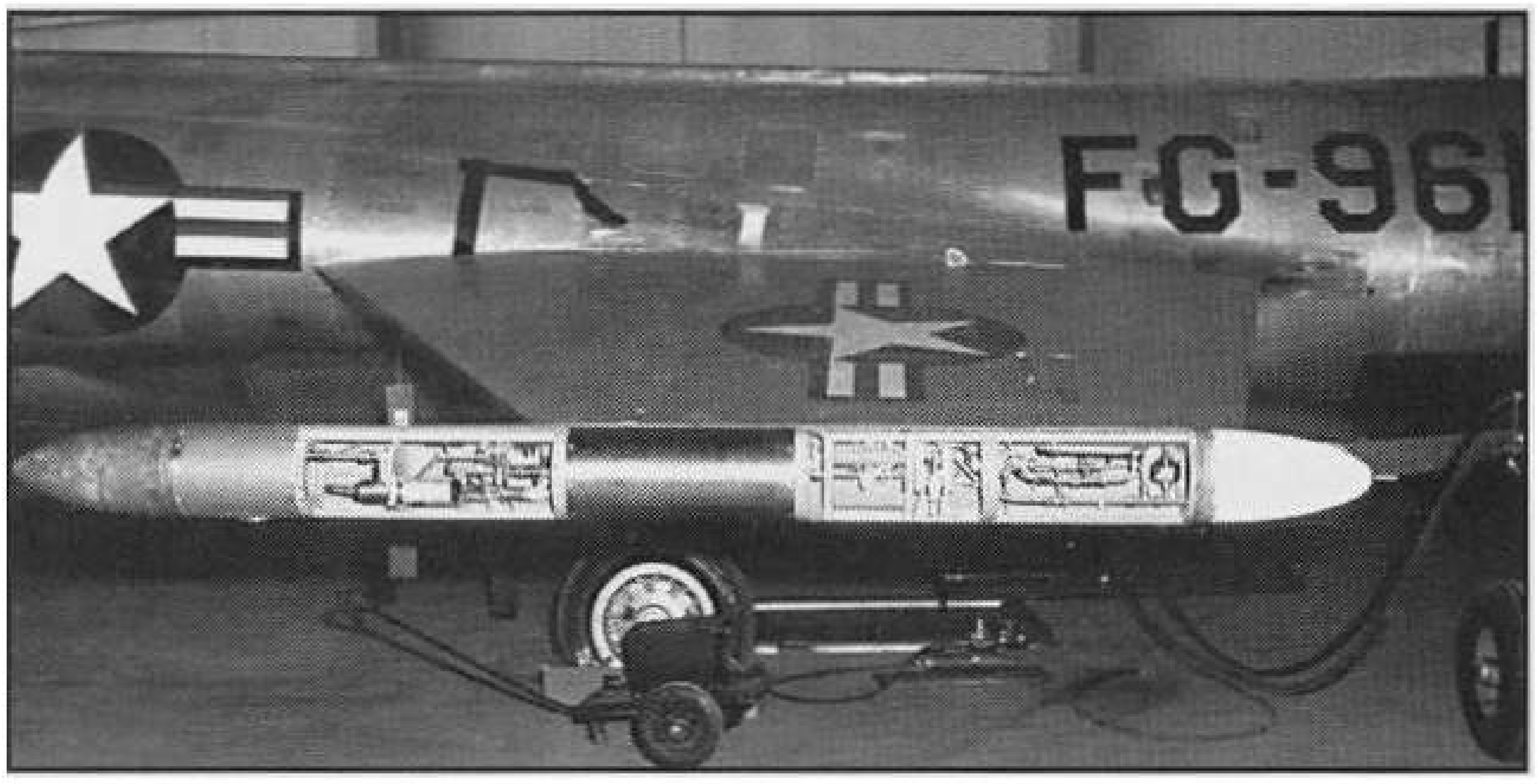
## METEMORPHOSIS TO AST

Extensive is the word that best describes the scope of the modification that transformed an F-104A into a aerospace trainer. Three "A" model F-104s, tail numbers; 56-756, 56-760 and 56-762, were selected for the modification. Total cost of the modifications for the three aircraft was $5,363,322. When completed, these trainers would provide a pilot experience in transition training from conventional aircraft to spacecraft. Flying the NF-104, a pilot would gain vital experience in the four phases of space flight: boost to sub-orbit, zero gravity (approximately two minutes), use of a reaction control system and reentry. The trajectory of a rifle bullet fired into the air is a good comparison when examining the flight profile of the NF-104. The bullet's trajectory (path) follows a ballistic arc. At the peak of the arc, the energy of the bullet has dissipated to a level where gravity becomes the influencing factor. The bullet then falls to earth. The same principals apply to the NF-104's

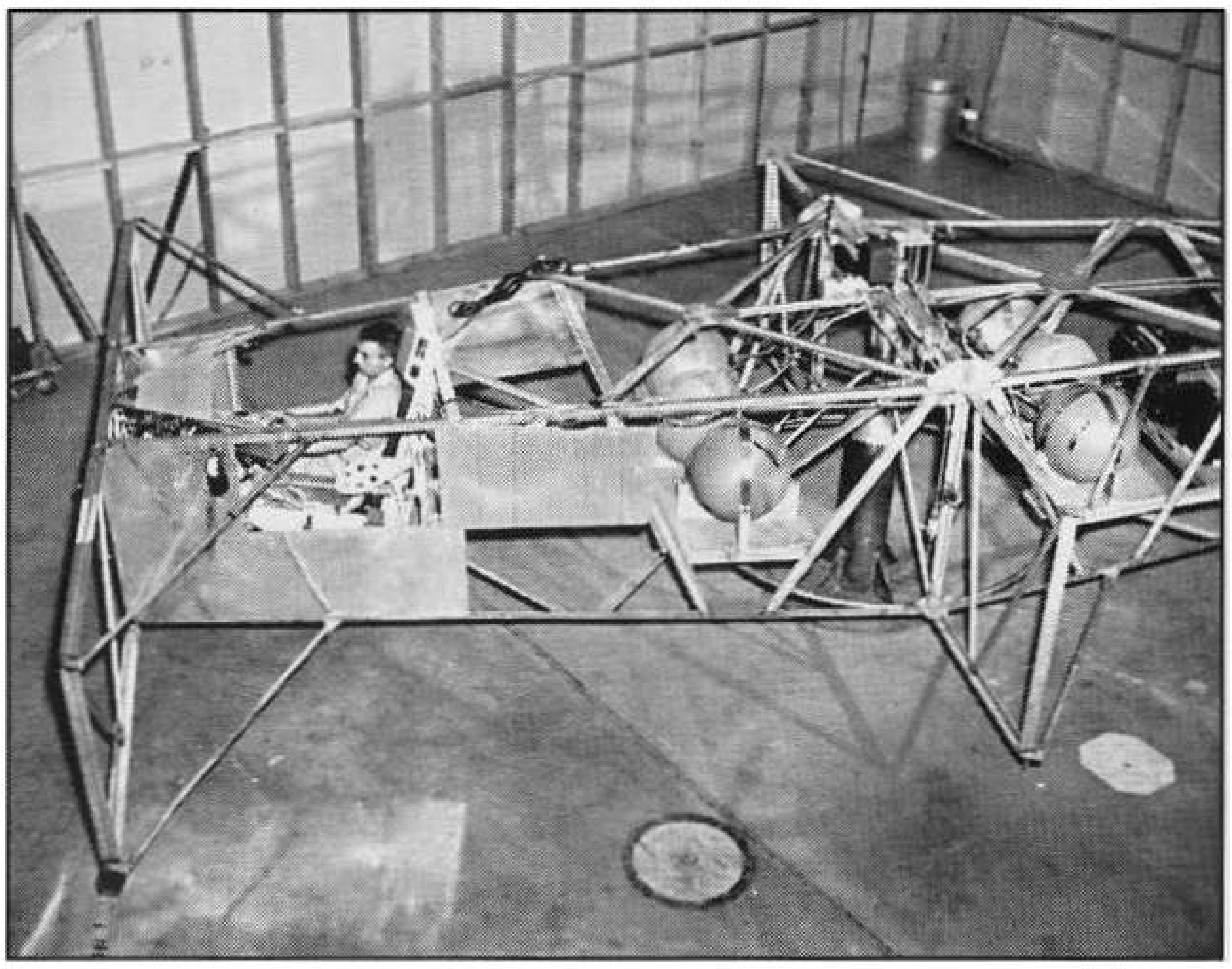
**Below, NASA #961 looking rearward from above. Wing tip RCS test pods are fitted on the missile rails. The outlets for the RCS pitch and yaw jets are seen in the forward nose. Also compare the stock inlets with the NF-104 inlets on page 41. (via Tony Landis)**







Above left, NASA #961's test instrument panel & forward cockpit. Above, test RCS roll pod on 55-2961. Below left, nose pitch and yaw stabilizing jets being tested on 961. Below, early RCS test rig. Bottom, wing tip tests of the roll RCS system. Aircraft had a yellow band across the tail with NASA in black letters. Nose, tail and outer wing panels were da-glo red. (NASA via Tony Landis)



zoom maneuver.

Nonessential equipment stripped from the F-104 airframe to make room for the aerospace trainer mod included; radar LRU's, fire control system, gun and ammunition drum and the auxiliary fuel tank. The "A" model empennage would be replaced with one from a TF-104G. Rationale for this being that the TF-104G model was a two-seat trainer and had a larger rudder. The AST's rocket engine would be located at the base of the rudder and overlap into the area of the rudder. The larger rudder would compensate for the lost area due to the rocket fairing installation, helping to maintain directional stability.

Canted at 8.5 degrees, the rocket's exhaust nozzle pointed upward, slightly, to allow the engine's thrust centerline to pass through the aircraft's center of gravity. This minimized pitch moments during rocket engine start and burnout. Two-foot wing extensions were added to each wing to aid in housing the roll RCS components and add additional lift. Gross weight of the AST rose 3,000 pounds over that of the standard "A" model, so the added wing area with accompanying lift was a welcome addition. The '104s fiberglass radome had to be replaced with a metal nose cone to protect the pitch and yaw RCS components along with their associated hydrogen peroxide tank. Mounted to the nose, the YAPS boom transmitted highly accurate yaw and pitch information to onboard recording equipment and cockpit displays. Further down, on either side of the fuselage, the engine inlet cones were lengthened to improve ram recovery at high Mach number. This improvement helped to optimize engine performance at high speed and high altitude.

The cockpit had to be gutted to accommodate all new instrument displays and RCS controls. Replacing the old attitude indicator on the forward instrument panel would be a new three axis azimuth reference system, suitable for training a student astronaut. A 50-channel recordable oscilloscope and an automatic observer camera were installed to document the various parameters of the flight profile. This information would be used to grade the student on how well he flew a given profile.

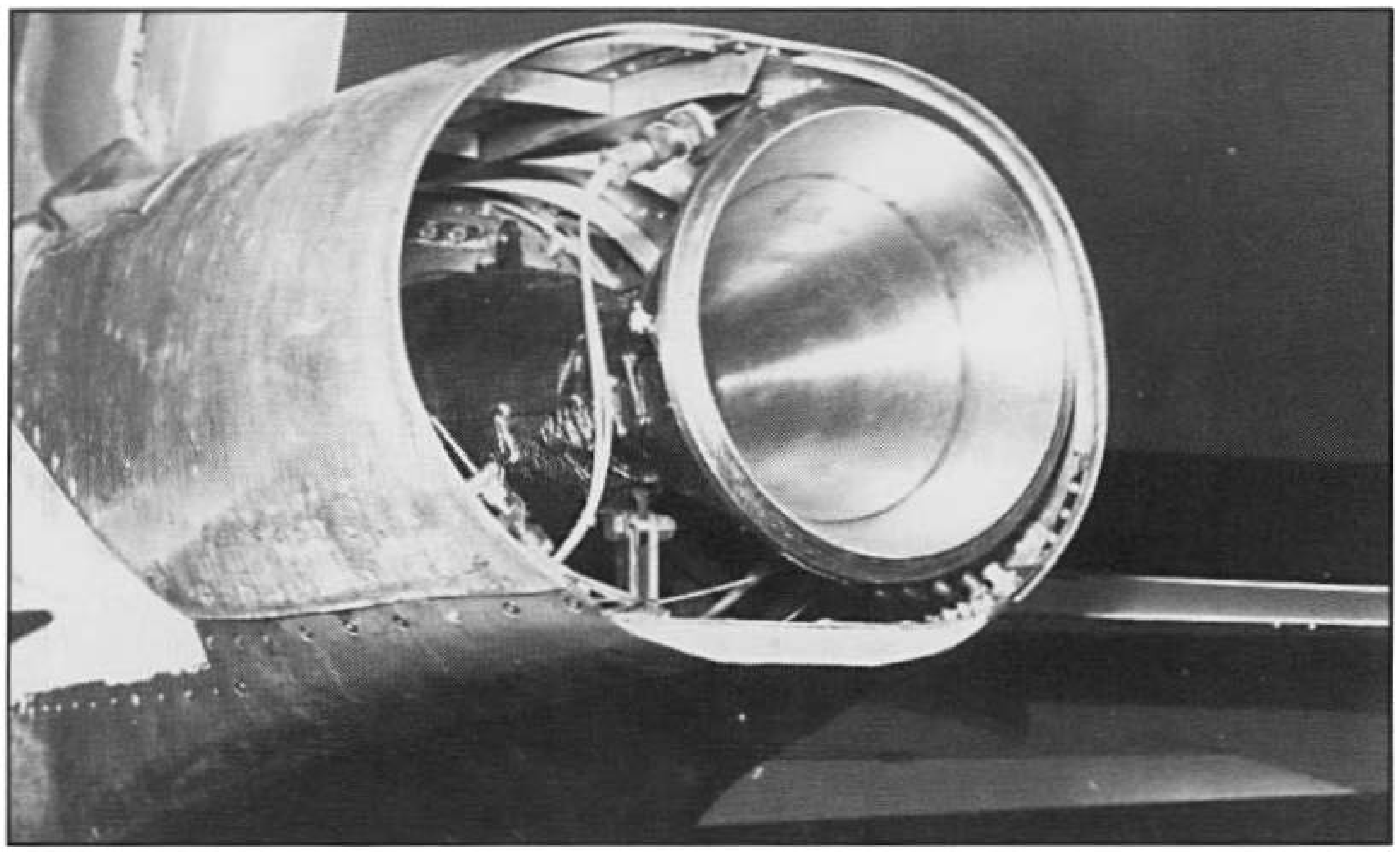
Special consideration was given to the aircraft systems that normally required an operating engine to function. The affected accessories driven by the engine were: an AC generator and compressor bleed air for the aircraft's air cycle machine (air conditioner). A necessary evil, the engine was shut down late in the zoom climb to prevent an engine over-temp, as will be discussed later on. In the new nose section, an additional 34 amp hour battery would supplement existing onboard batteries and compensate for the loss of the engine driven generator.

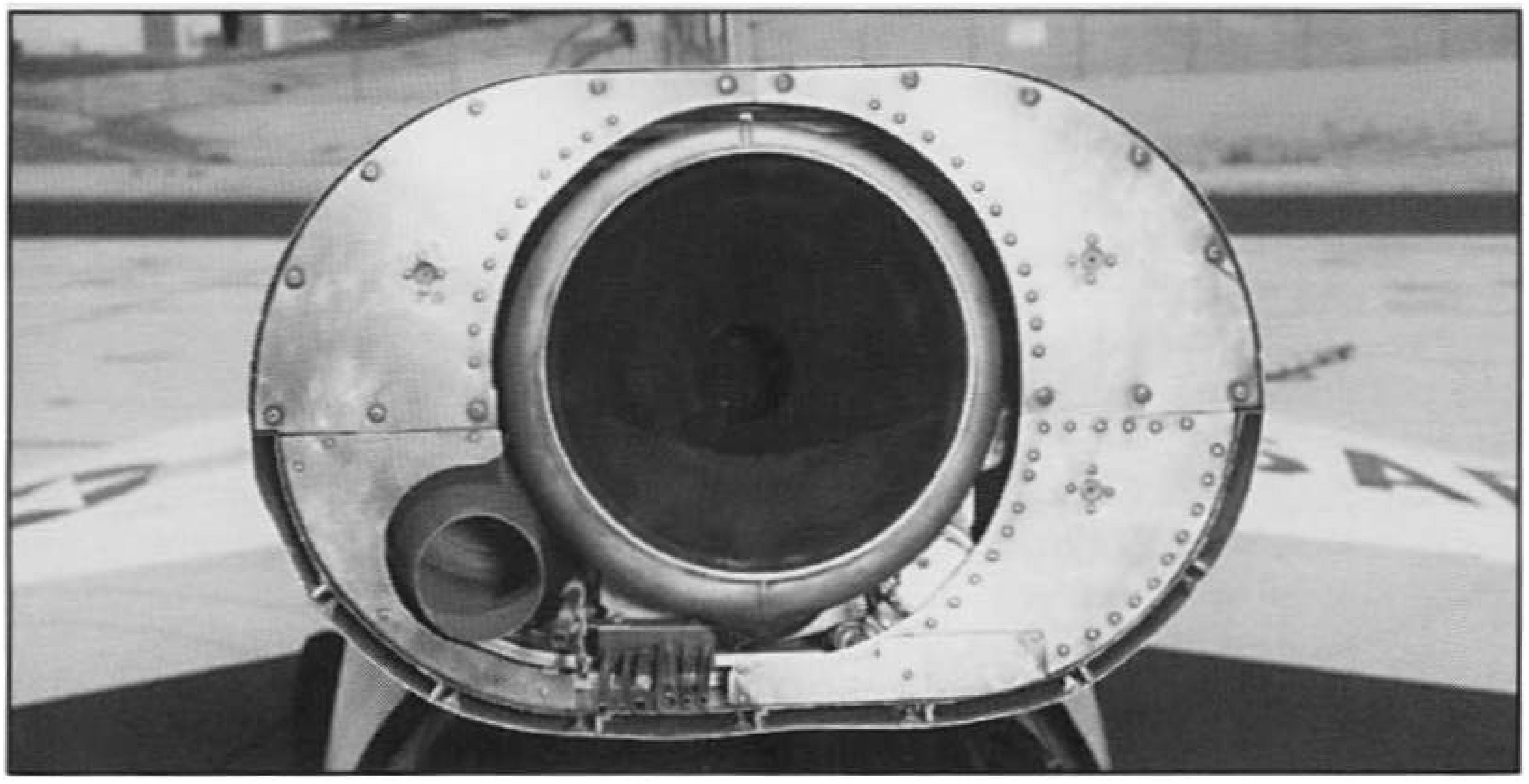
Most important, normal cockpit pressurization air is bled off the compressor from the engine and then conditioned though an air cycle machine. A gaseous nitrogen system placed in the former gun bay now would supply cockpit pressurization during the portion of the flight when the engine would be shut down. Engine bleed air is used to pressurize the cockpit up to 35,000 feet, where at that point, the nitrogen system takes over to maintain a constant 35,000 foot cabin pressure. Because of the extreme altitudes being flown, the pilots wore pressure suits, similar to the ones used by the Mercury and Gemini astronauts. Students gained additional space flight experience by working in an inflated pressure suit.

Lockheed and the Air Force had been zooming their F-104s for years, routinely reaching 80,000 feet. 1959 saw Air Force Capt Joe Jordan set an altitude record of 103,000 feet in a standard F-104 long before the NF-104 came along. It goes without saying that '104 pilots were well versed in working with pressure suits. The Aerospace Research Pilots School lost a student when a coupling on his pressure suit opened without warning. The student had taxied his F-104 to the end of the runway, where he was parked doing the "last chance" check list. Calling back to the radio room, he said his glove was giving him troubles. He then took the glove off and repositioned it himself. Apparently, satisfied with the fit, he requested and received clearance to take off. The flight proceeded normally, until sometime well into the zoom, the repositioned glove popped off causing the suit to loose pressure. The student lost consciousness soon thereafter and never recovered. The subsequent crash investigation revealed that the student had failed to reconnect the glove correctly.

**Above, four F-104As taxi in unison at Edwards AFB open house in 1962. 60-762, 60-760, and 60-756 were converted into NF-104 aircraft. (Stan Wyckoff via Craig Kaston)**

Critics of the AST were concerned about the lack of redundancy in two of the most critical aircraft systems. Some were concerned over the lack of redundancy regarding the primary J79 engine. Why would you want to shut down your only engine during the most dangerous phase of the maneuver? What if the engine refused to restart? Were there twin





engine aircraft, like Northrop's T-38, that were better suited for the task? Another point of contention was the pilot's pressure suit's vulnerability to a single point failure. There was no backup for the pilot in the event of a catastrophic suit failure. Again, during the most critical phase of the flight, the cockpit was pressurized with nitrogen. This environment would not sustain life; was this a prudent arrangement? Lockheed and the Air Force pressed on citing the safety record of the X-15, which was a similar configuration.

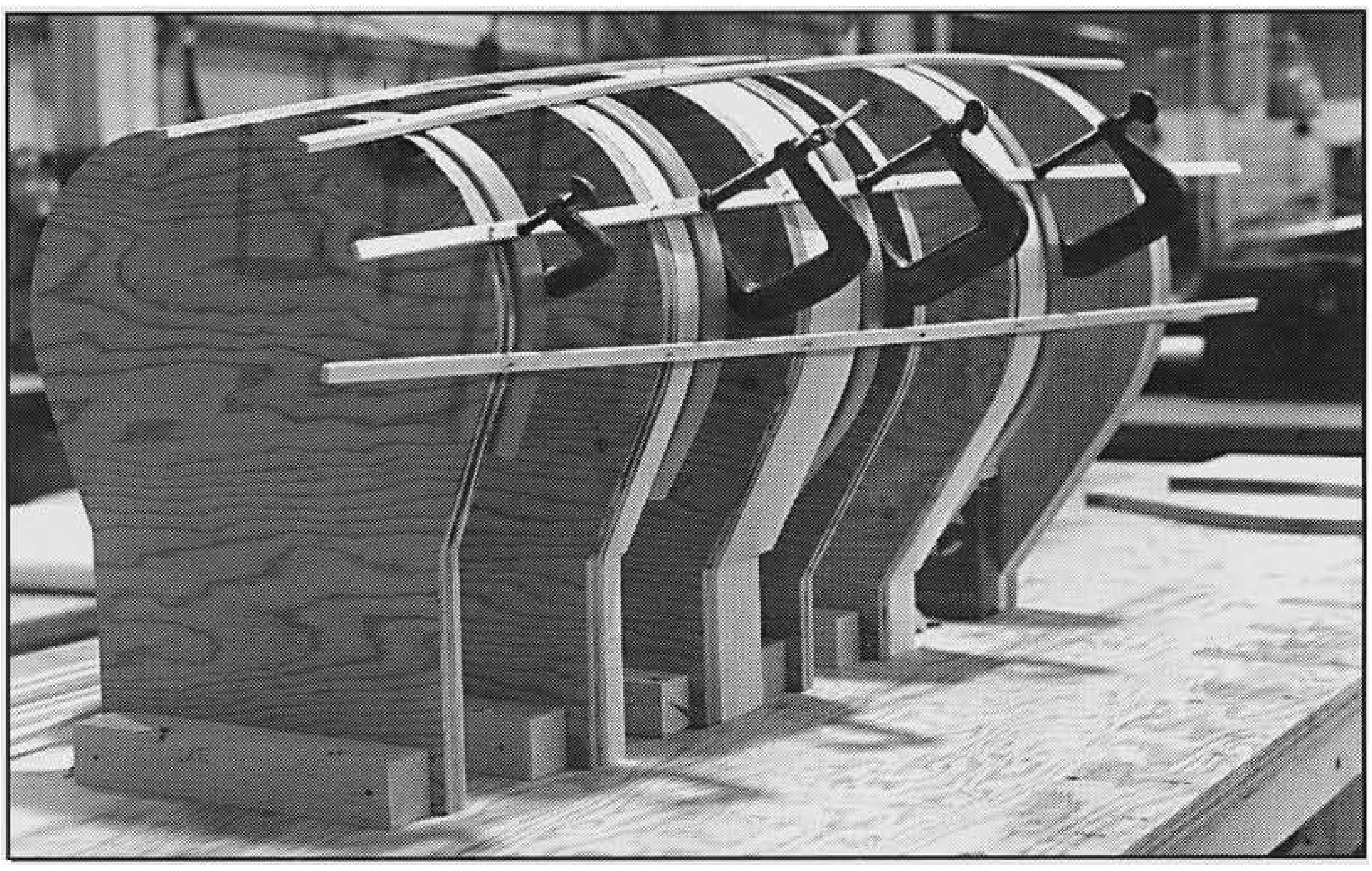
## THE AR2-3 ROCKET ENGINE

Rocketdyne's AR series of aircraft rocket engines dates back to 1953, when a scaled version was test fired producing 1,000 pounds of thrust. Results of this initial test were so promising that further development led to a rocket engine capable of 6,000 pounds of thrust. Before being selected by Lockheed for the Aerospace Trainer, the Navy and Air Force Fitted FJ-4F and F-86F aircraft with the AR2-3 to explore possible combat applications. The concept under consideration here was whether the rocket engine could be used to improve dash speed to enable a pilot to overtake, or if necessary, evade an enemy aircraft. The Navy conducted tests with its FJ-4F, making 103 flights and accumulating 3.5 hours of AR2-3 engine operation. Likewise, the Air Force ran similar tests with an F-86 compiling 31 flights and 1.4 hours of engine run time. Although a production contract would not be forthcoming, it did provide Rocketdyne more time to refine the design.

Among the strong selling points of the AR2-3 were the variable thrust and multistart features, along with its compact size. JP-4 and hydrogen peroxide ($H_2O_2$) were the fuel and oxidizer utilized by the engine. The AST's primary (J-79) engine used JP-4 fuel, so it wasn't necessary to construct a separate tank for storage. Separate tankage would be necessary for the hydrogen peroxide (oxidizer) which is the oxygen source needed for combustion. Two hydrogen peroxide tanks were built and installed just forward of the main JP-4 fuel cell, replacing the auxiliary fuel cell on the F-104. Total capacity of the two tanks was 226 gallons, and that would be enough propellant to sustain rocket engine operation for approximately 100 seconds. Mixture ratio was about six pounds of hydrogen peroxide to one pound of fuel.

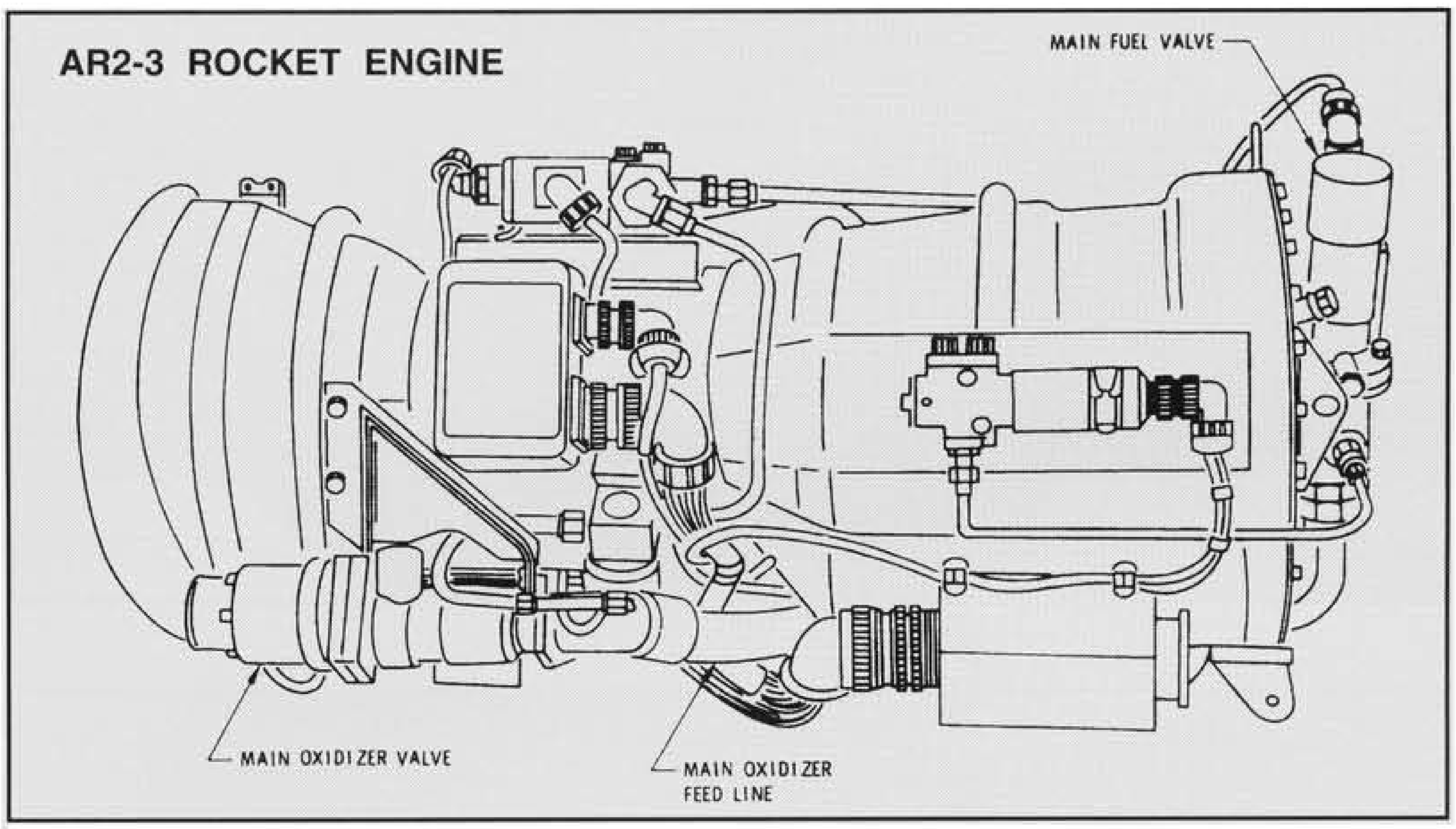
A turbopump supplied pressurized fuel and oxidizer to the thrust chamber of the AR2-3, which mixed the bipropellants for combustion. The turbopump was driven by a gas generator that was also powered by hydrogen peroxide to produce superheated steam. A reaction took place when the hydrogen peroxide entered the gas generator containing a pack of fine silver-plated screen. The silver plated screen served as a catalyst, accelerating the decomposition of the hydrogen peroxide, resulting in superheated steam and releasing the oxygen. This superheated steam drove a turbine within the turbopump, which drove two separate pumps on a common shaft for the fuel and oxidizer. The turbopump now supplied pressurized fuel and oxidizer to the combustion assembly. Pressurized fuel was then pumped though drilled orifices of the injector into the combustion chamber. The oxidizer pump circulated hydrogen peroxide though the outer jacket of the combustion chamber, cooling the engine during operation. From the cooling jacket, the hydrogen peroxide was introduced into a catalytic screen pack (similar to the one in the gas generator) and again, the peroxide decomposed, generating 1,365F degree superheated steam. Now the superheated steam and oxygen mixed with the fuel in the combustion chamber, where the mixture autoignited producing thrust for propulsion.

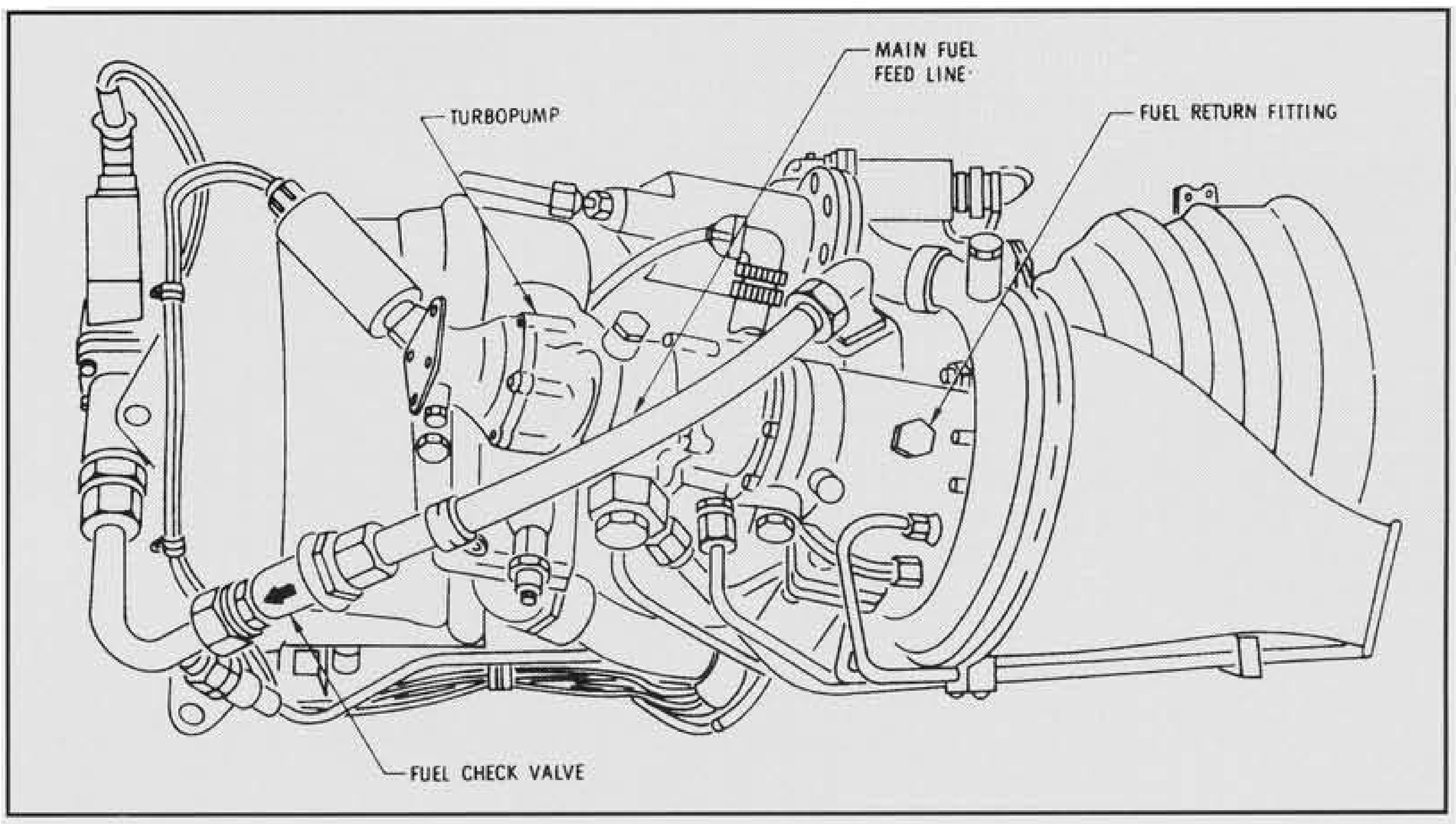
Maintenance and serviceability of the AR2-3, which would also be known as the LR121-NA-1, required diligence and close attention to detail. After 60 minutes of engine operation, a minor overhaul would be performed to replace worn parts. After 120 minutes of operation, a major overhaul would be necessary, requiring the

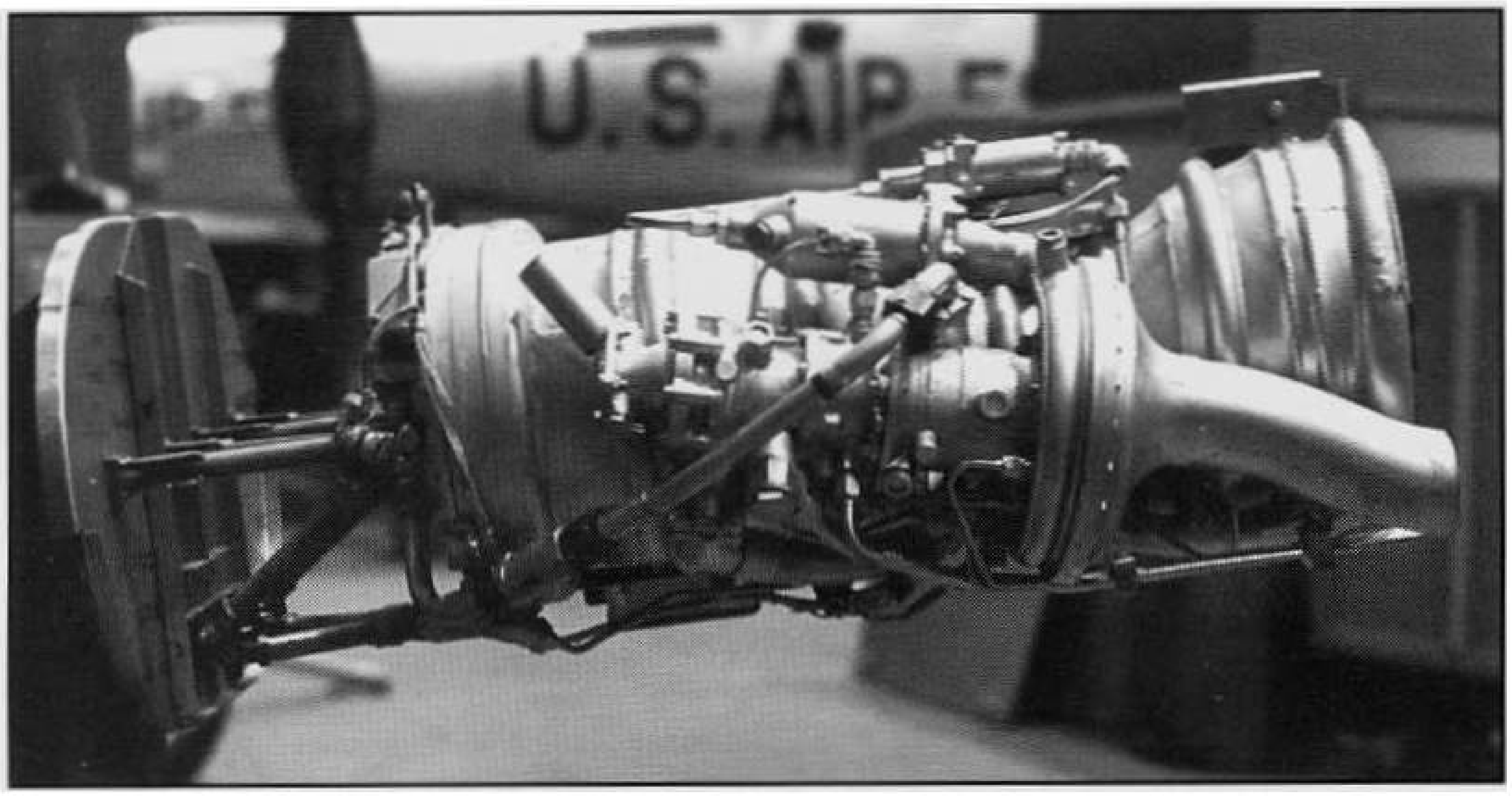


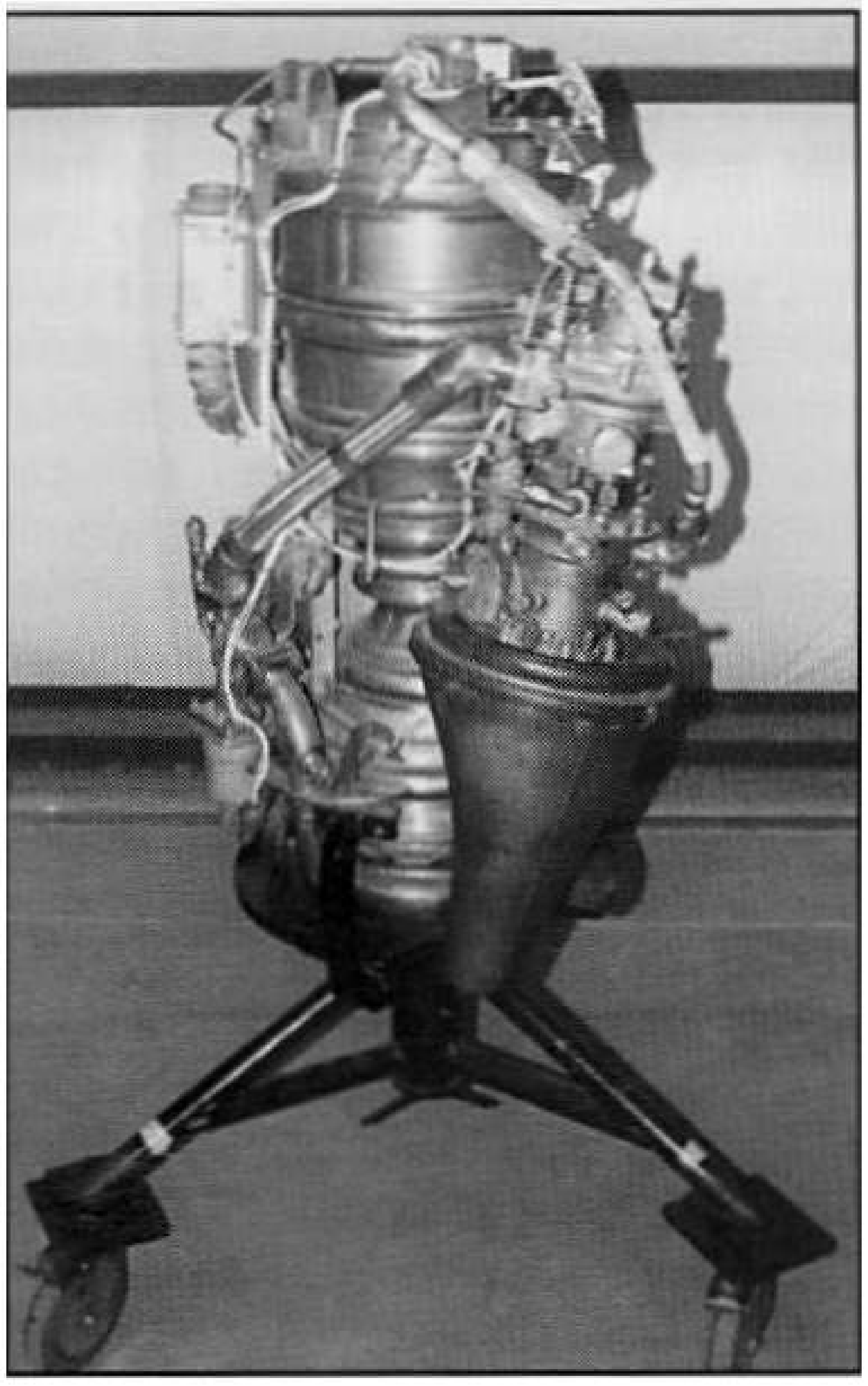
**At left top, FJ-4F rocket powered research aircraft. At left, FJ-4F AR2-3 rocket installation. (NAA) At lower left, F-86F 52-4608 was also equipped with an AR2-3 rocket engine seen in a fairing behind the wings. (via Fred Freeman) At left bottom, NF-104A rocket installation. (via Kaston)**

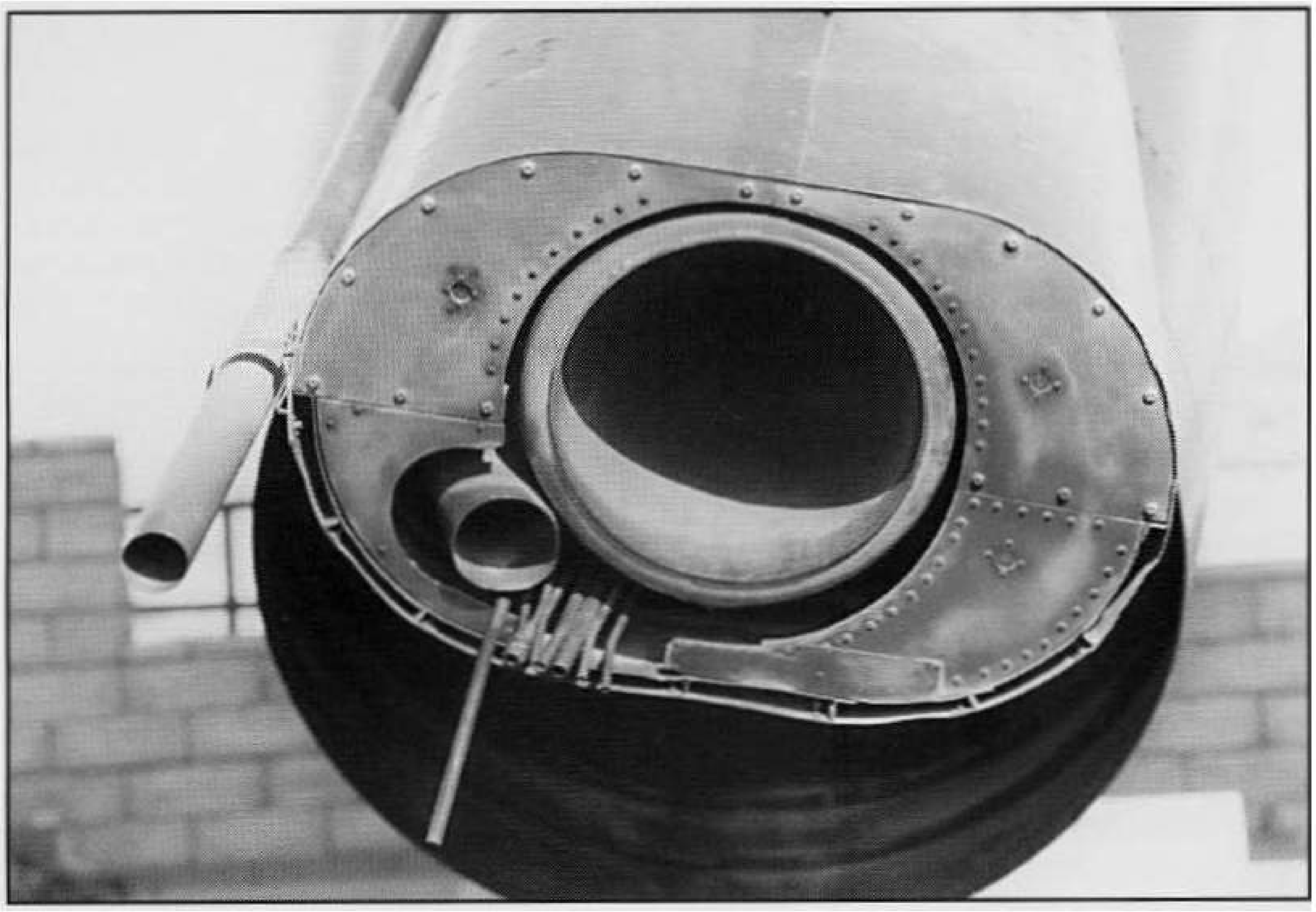
**Above, NF-104A rocket fairing mock-up under construction. (Lockheed via Tony Landis)**



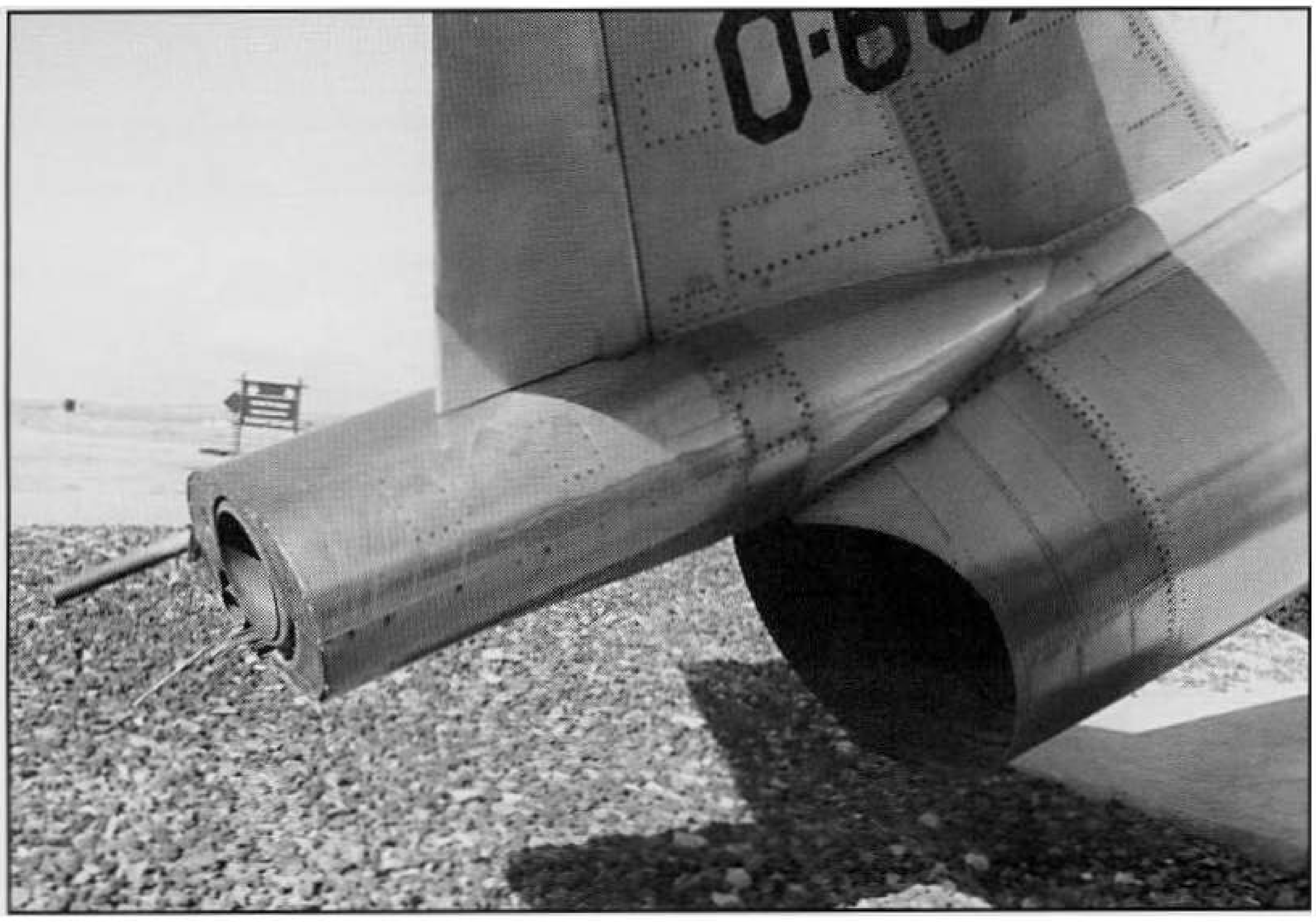


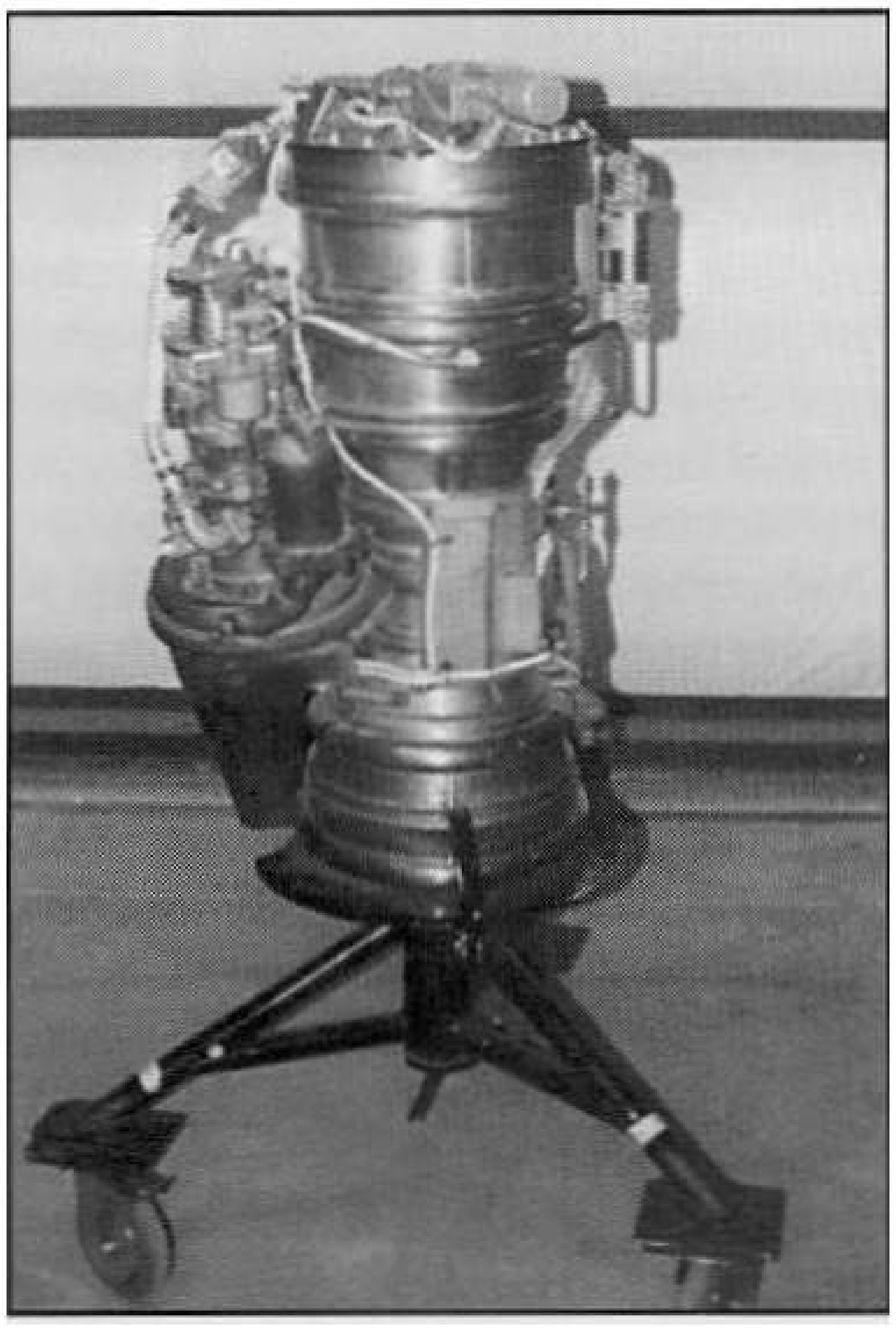


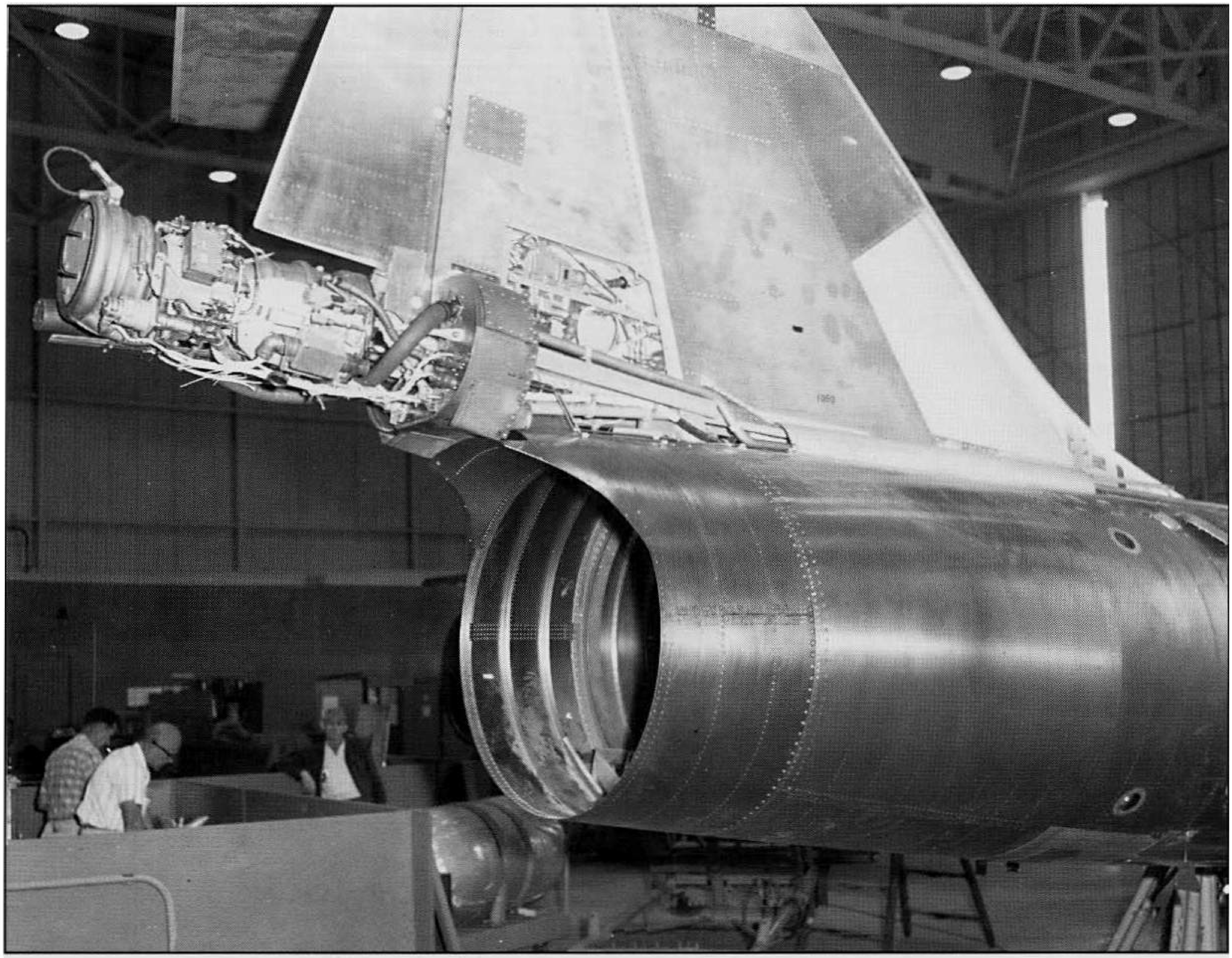


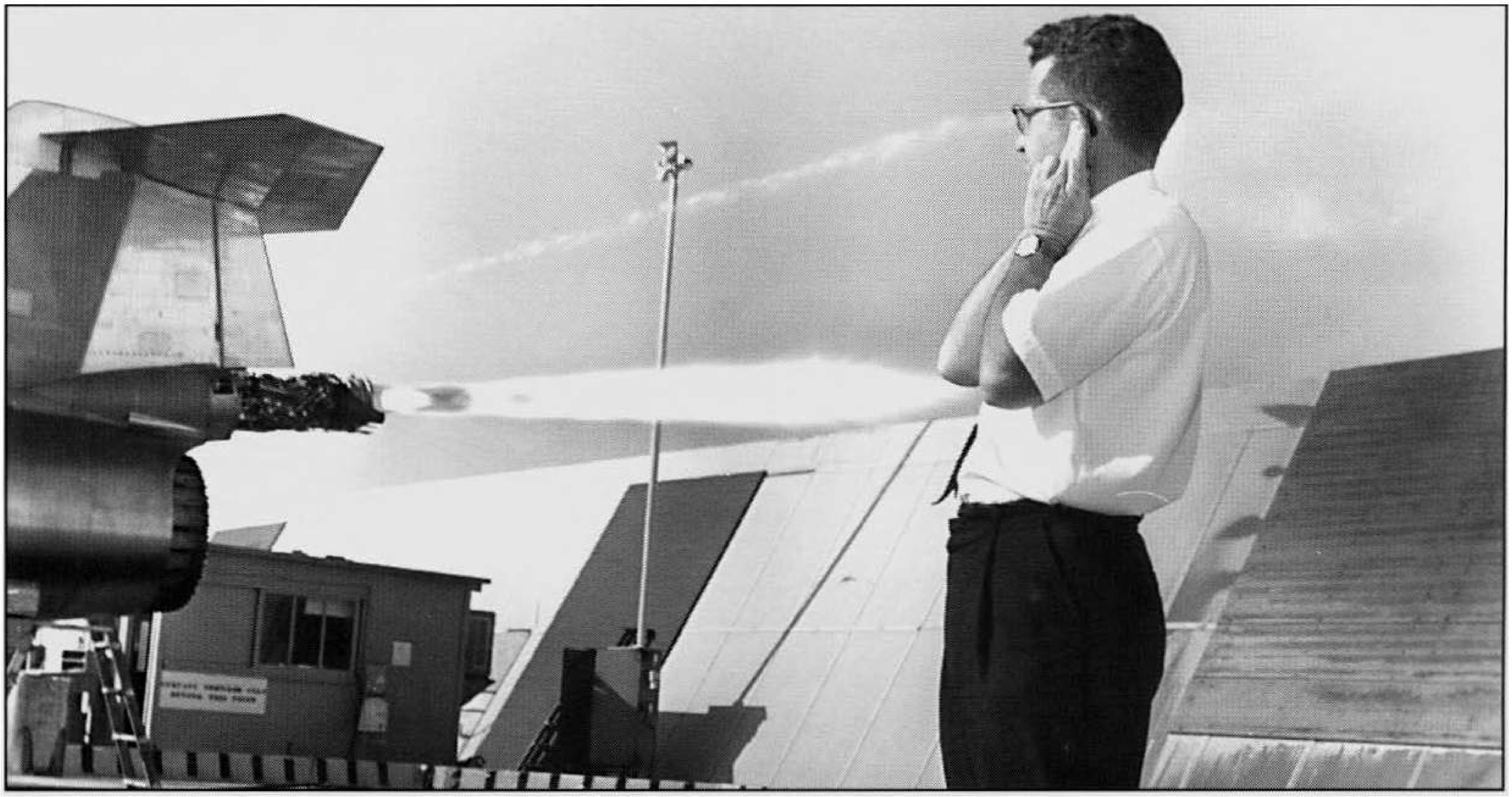


Above left, rocket engine bolted to the engine stand. (via Tony Landis) At left, close up of rocket exhaust. The pipe on the left side of the fuselage was the dump mast which was added as part of a gaseous nitrogen purge system. (Scott Libis) Below left, close up view of the rocket motor fairing. (Scott Libis) Above and below, the AR2-3 rocket engine that is on display at the AFFTC museum at Edwards AFB. (Scott Libis) At right top, rocket engine installation in the tail of 762 without the external skin. (via Tony Landis) At right bottom, rocket engine test. (via Tony Landis)

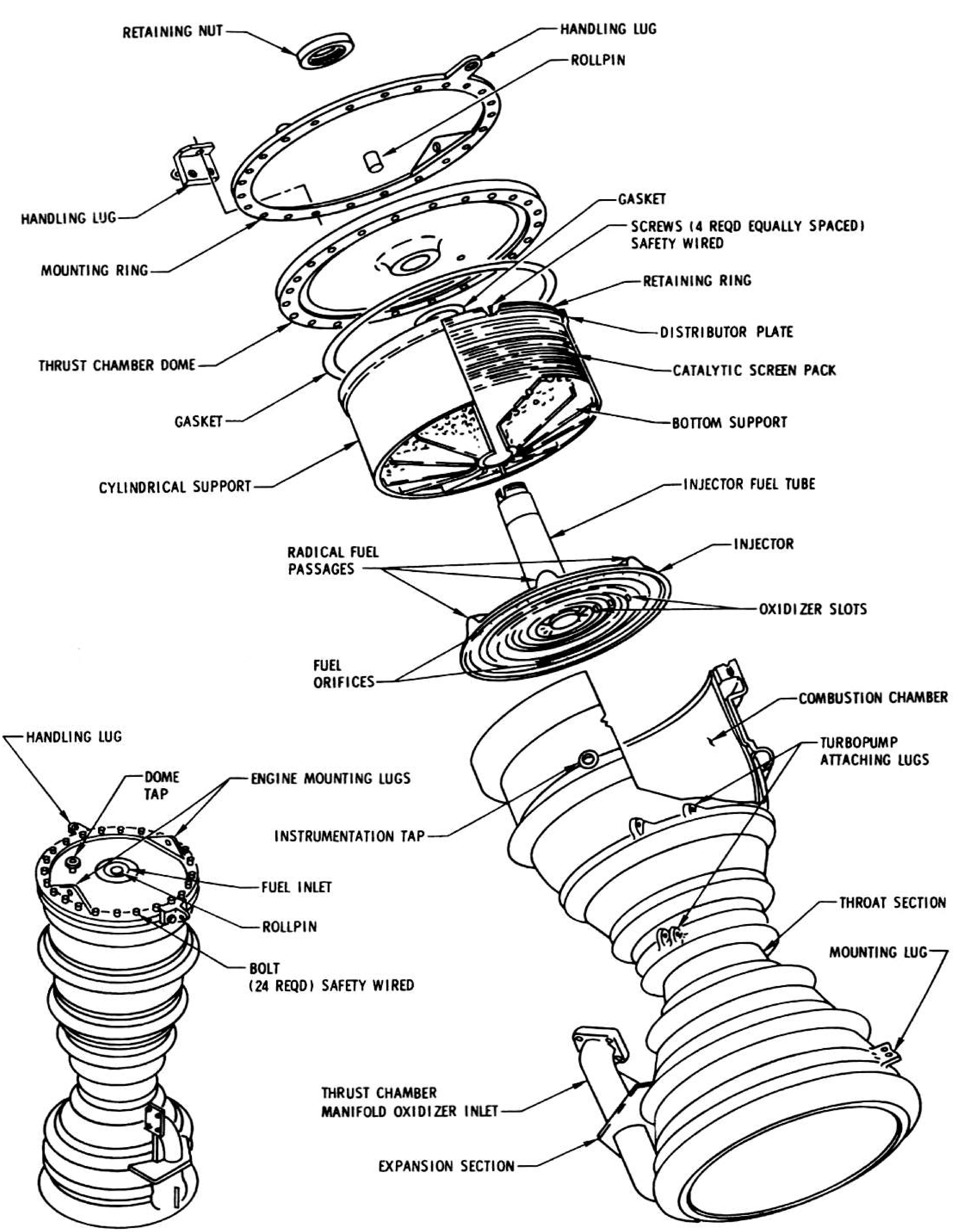






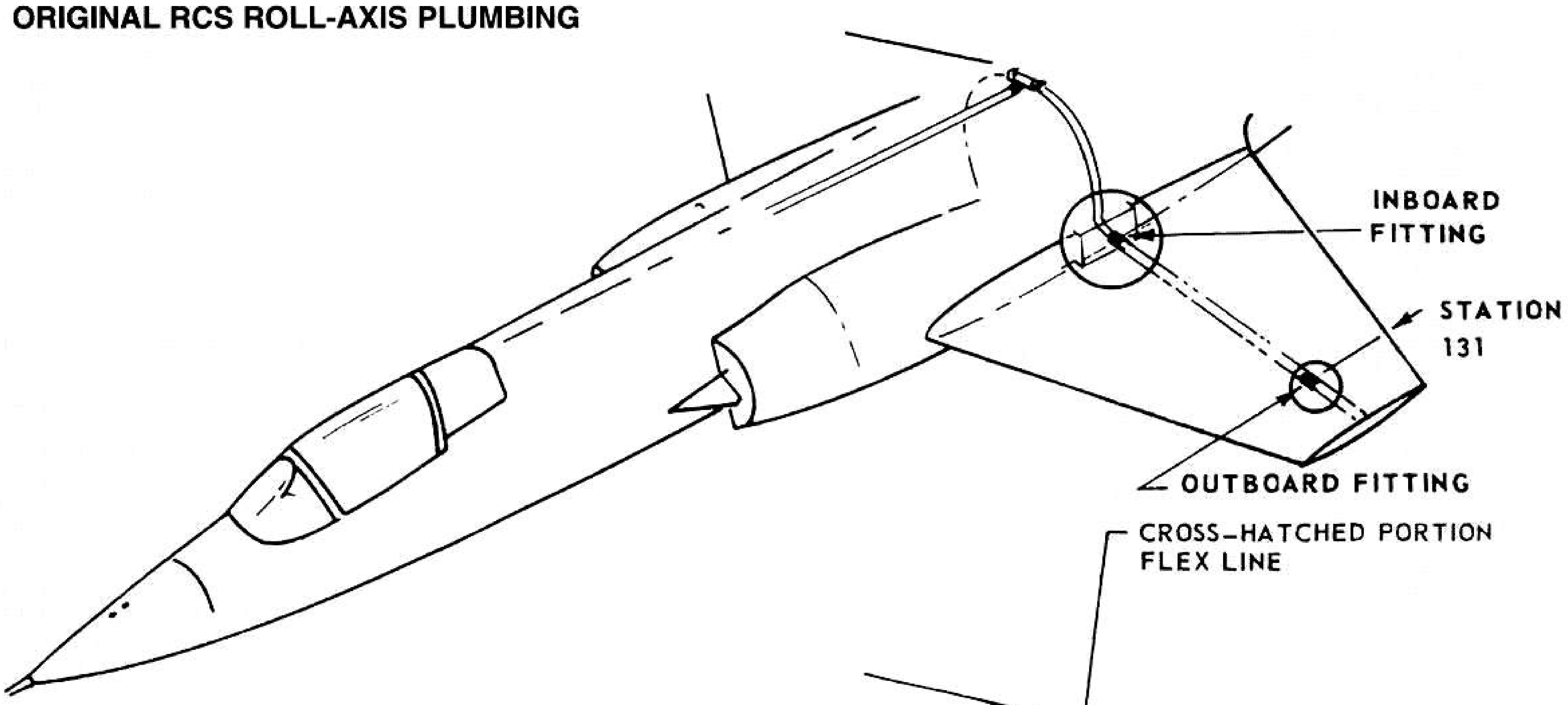


# AR2-3 ROCKET ENGINE THRUST CHAMBER ASSEMBLY

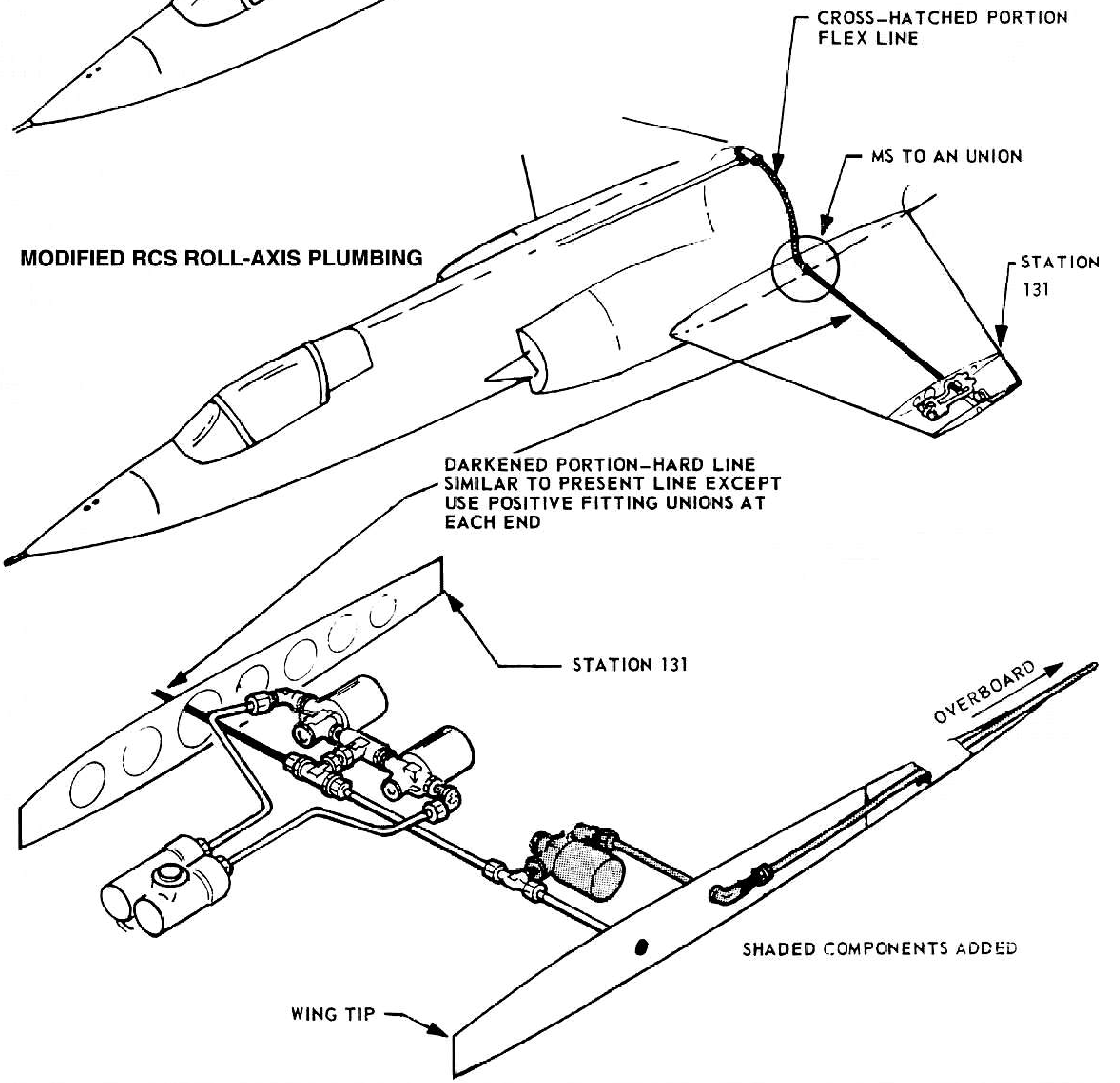


# RCS ROLL - AXIS PLUMBING: ORIGINAL AND MODIFIED

**ORIGINAL RCS ROLL-AXIS PLUMBING**



**MODIFIED RCS ROLL-AXIS PLUMBING**

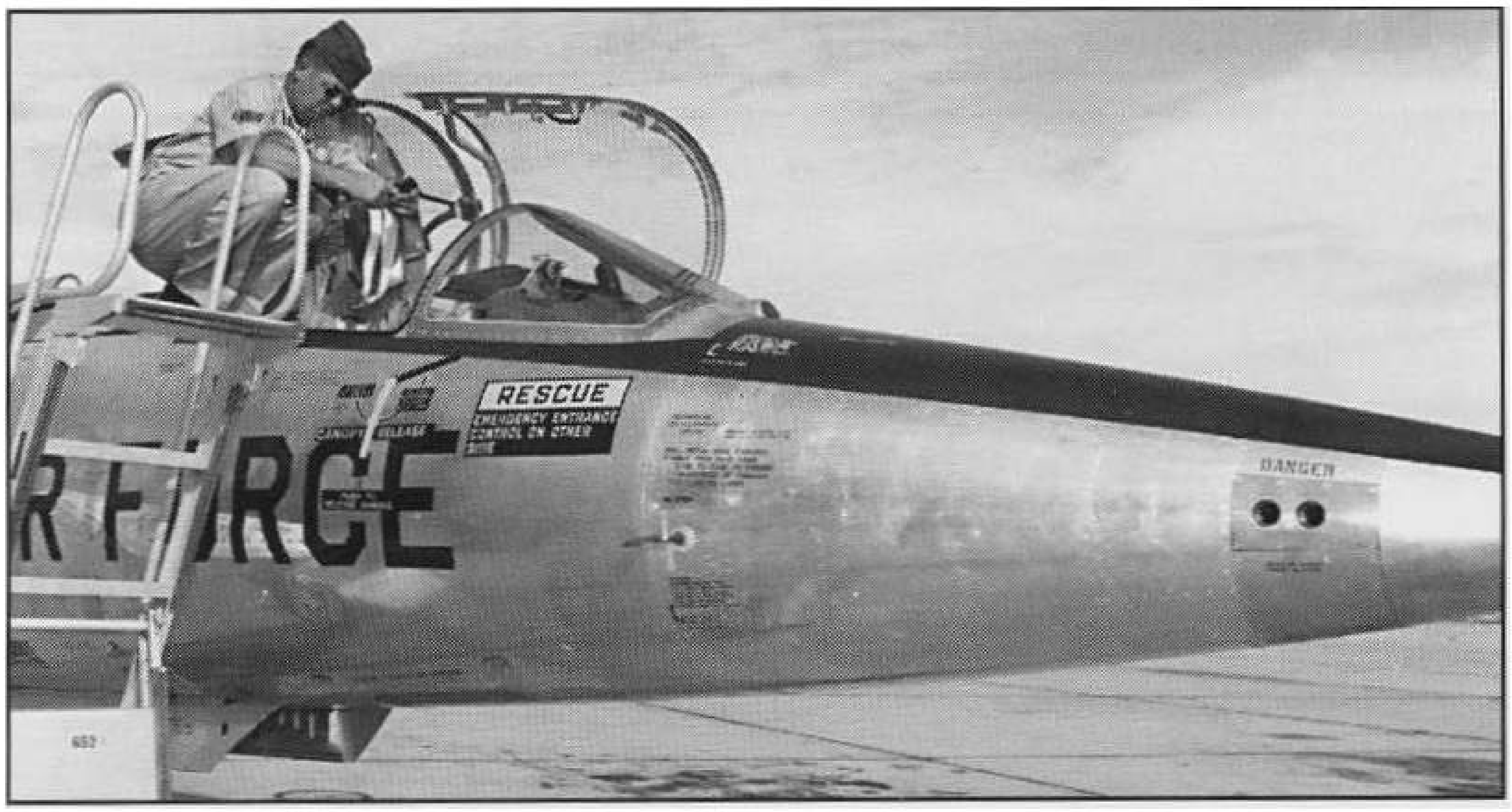

CROSS-HATCHED PORTION FLEX LINE
MS TO AN UNION
STATION 131
DARKENED PORTION-HARD LINE SIMILAR TO PRESENT LINE EXCEPT USE POSITIVE FITTING UNIONS AT EACH END
STATION 131
OVERBOARD
SHADED COMPONENTS ADDED
WING TIP

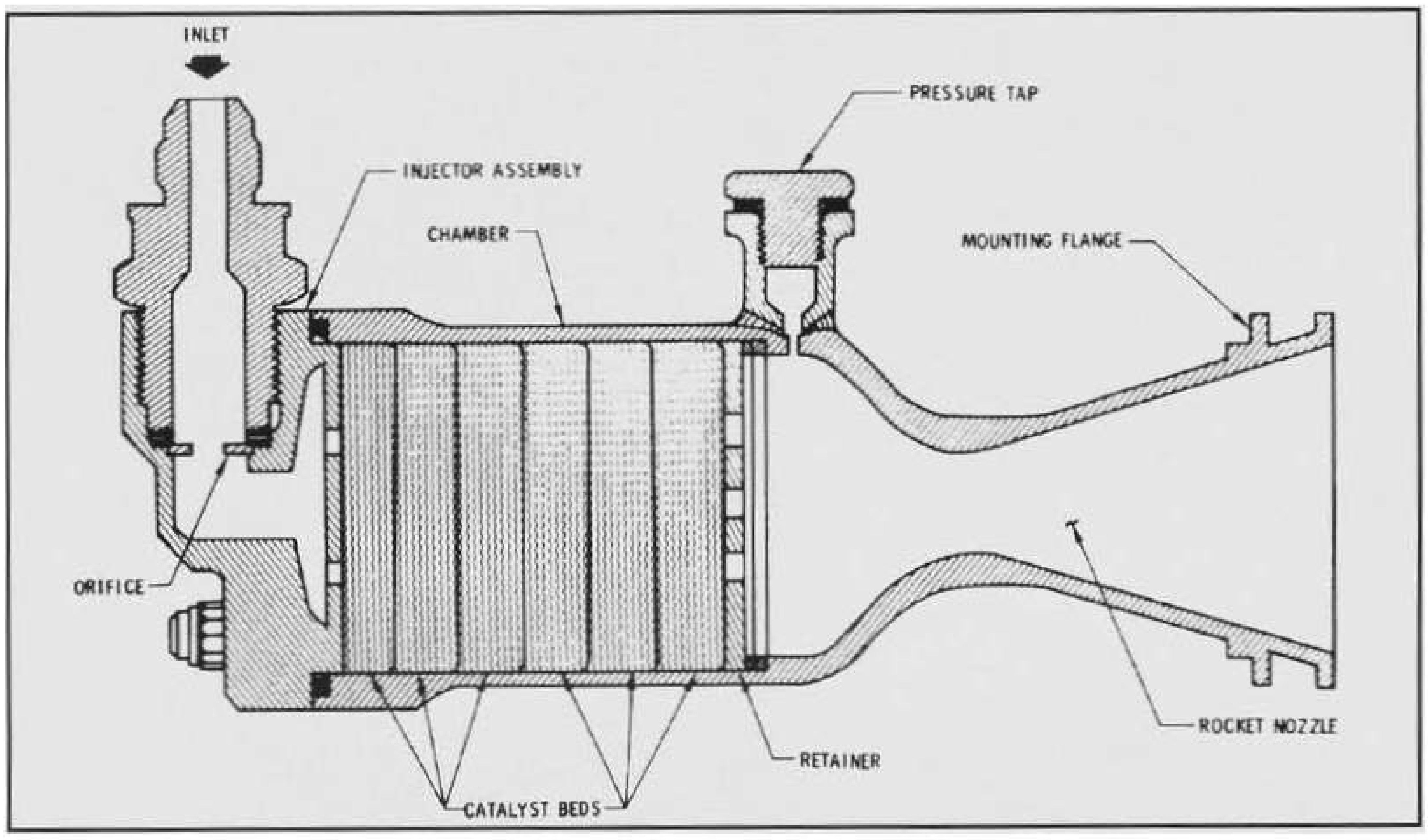
replacement of additional components. According to a Rocketdyne document, on one occasion, an engine was operated continuously for 15 minutes with no anomalies reported. A normal service life of four hours for each engine was expected. An upgraded version of the AR2-3 is currently being studied by Boeing Rocketdyne for possible use on the proposed X-37, Future-X space maneuvering vehicle.

## REACTION CONTROL SYSTEM (RCS)

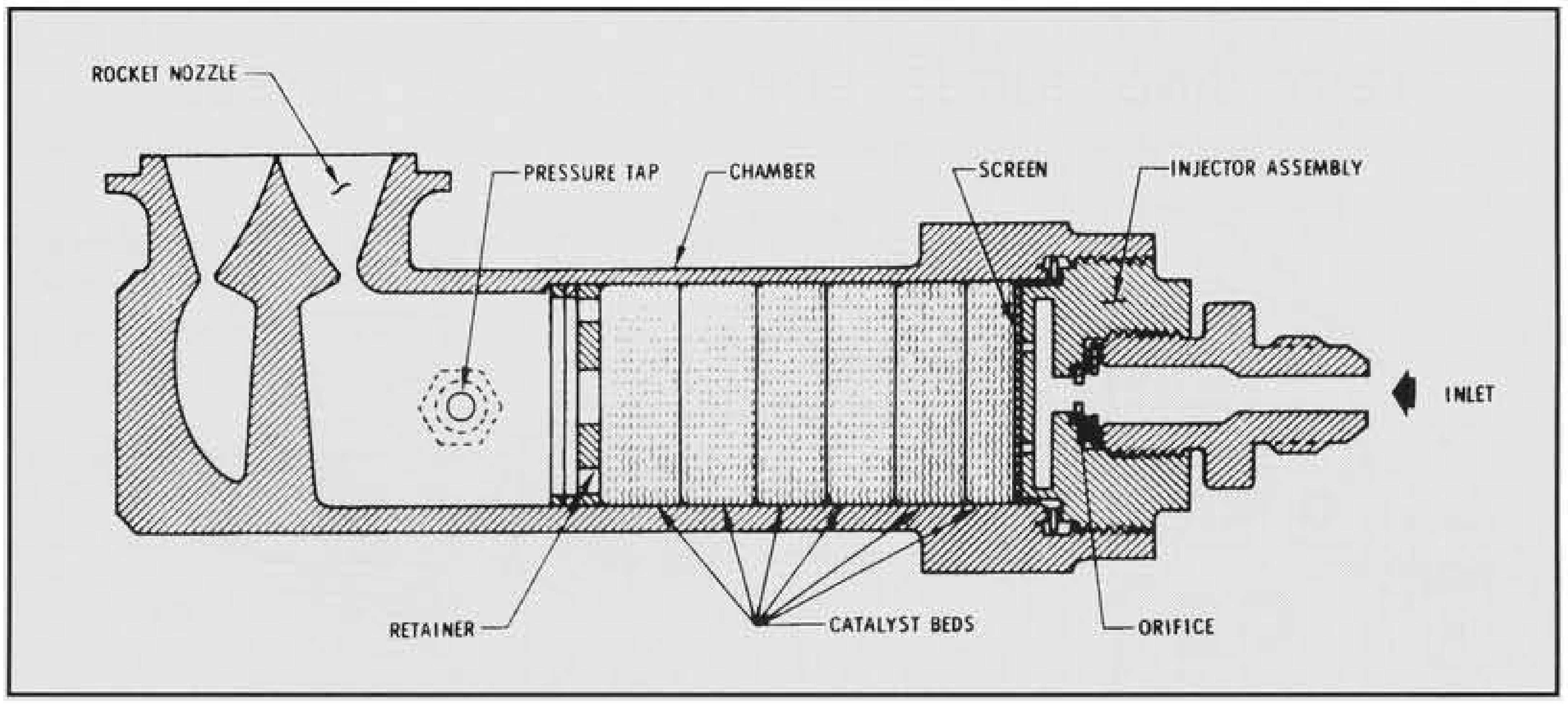
The Aerospace Trainers primary mission was to provide the student pilot experience in the four phases of space flight: boost to orbit, zero gravity, RCS Familiarization and re-entry. Vehicle attitude control, once in orbit, would rely solely on a number of reaction control thrusters situated at various locations on the vehicle. Fired individually, these tiny rocket motors enabled the astronaut to control his vehicle's flight attitude in all three axis. Although the AST was not designed to achieve orbit, it would fly in excess 100,000 feet, where the dynamic pressure would be low enough to allow the aircraft's RCS to become effective. albeit short in duration.

Dynamic pressure, or "q", refers to the force of the air impacting the exterior of the aircraft. The unit of measure for "q" is psf, or pounds per square foot. Airspeed and atmospheric pressure are the two determining factors when calculating "q". For instance, two aircraft are traveling at the same ground speed, yet one is at 30,000 feet and the other is at 10,000. The aircraft flying at 10,000 feet would be experiencing the higher "q" of the two, because atmospheric pressure is greater at lower altitude.





**Top, close up of the yaw RCS ports on the lengthened NF-104A nose. (Lockheed via Tony Landis) Middle, diagram of the pitch and yaw motor. (via Scott Libis) At left, Lockheed Test Pilot Jack Woodman points to wingtip RCS roll motor on 762. (Lockheed via Tony Landis)**



**At right, wing-mounted roll reaction motor diagram. (via Scott Libis)**

If the aircraft at 30,000 feet were to increase speed, a corresponding increase in "q" would occur. Airspeed has a diminishing effect on "q" the higher the aircraft flies. In the vacuum of space, "q" is zero.

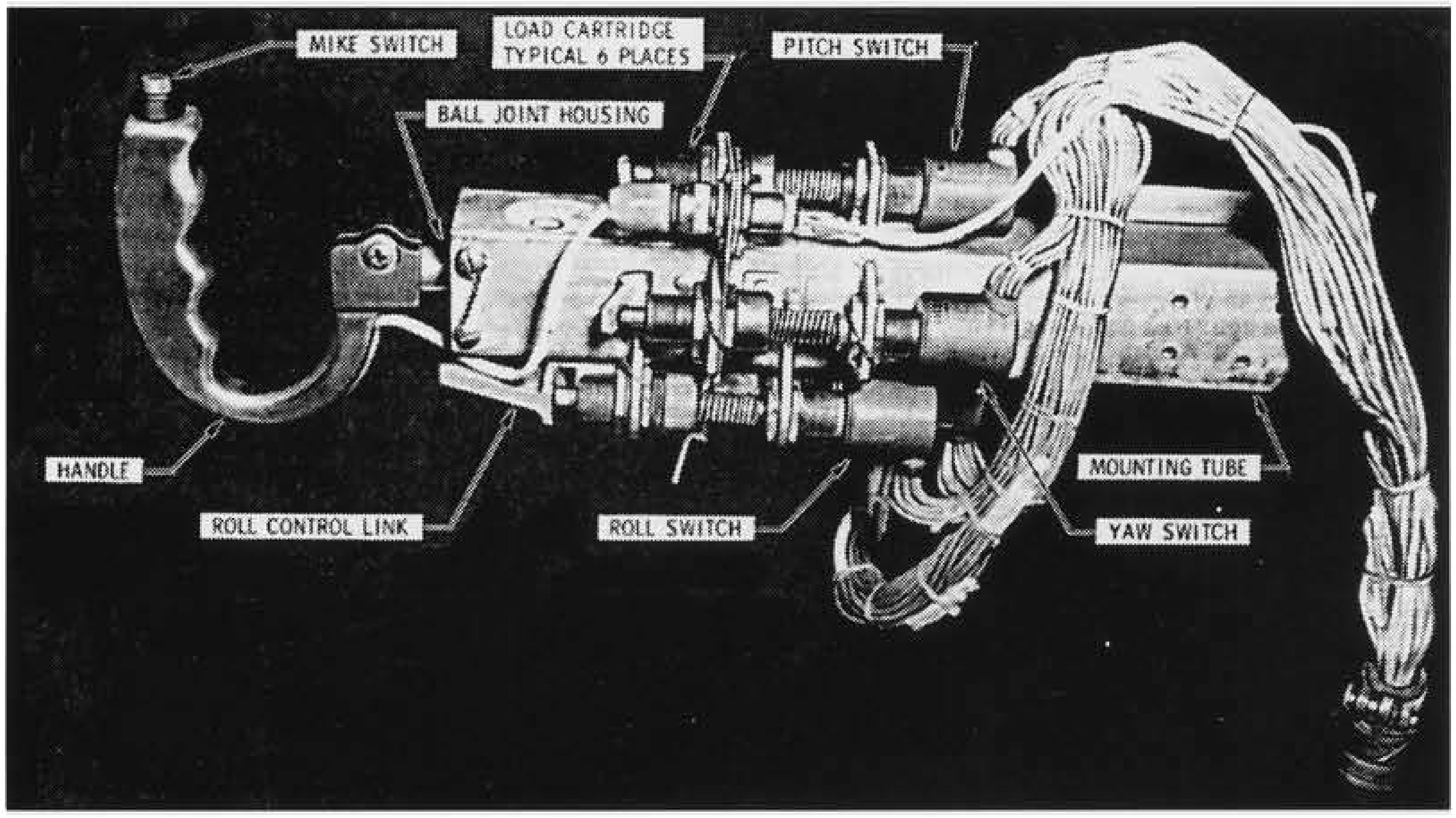
`"q" becomes very significant when planning for a zoom mission. At 100,000 feet, atmospheric pressure is a fraction of what it is at sea level, so it becomes important to know when the dynamic pressure has dropped below the threshold for the aerodynamic flight control surfaces. Eventually, the use of the rudder and ailerons will become so sluggish that they will have little effect controlling the aircraft as the point of low-q nears. At this point of low-q, the transition is made to the reaction control system.

Flying since 1959, the X-15 had pioneered the use of just such system with great success. Lockheed engineers quickly adapted the X-15's RCS components and layout for their design. The AST's final configuration would come to be known as "a poor man's X-15".

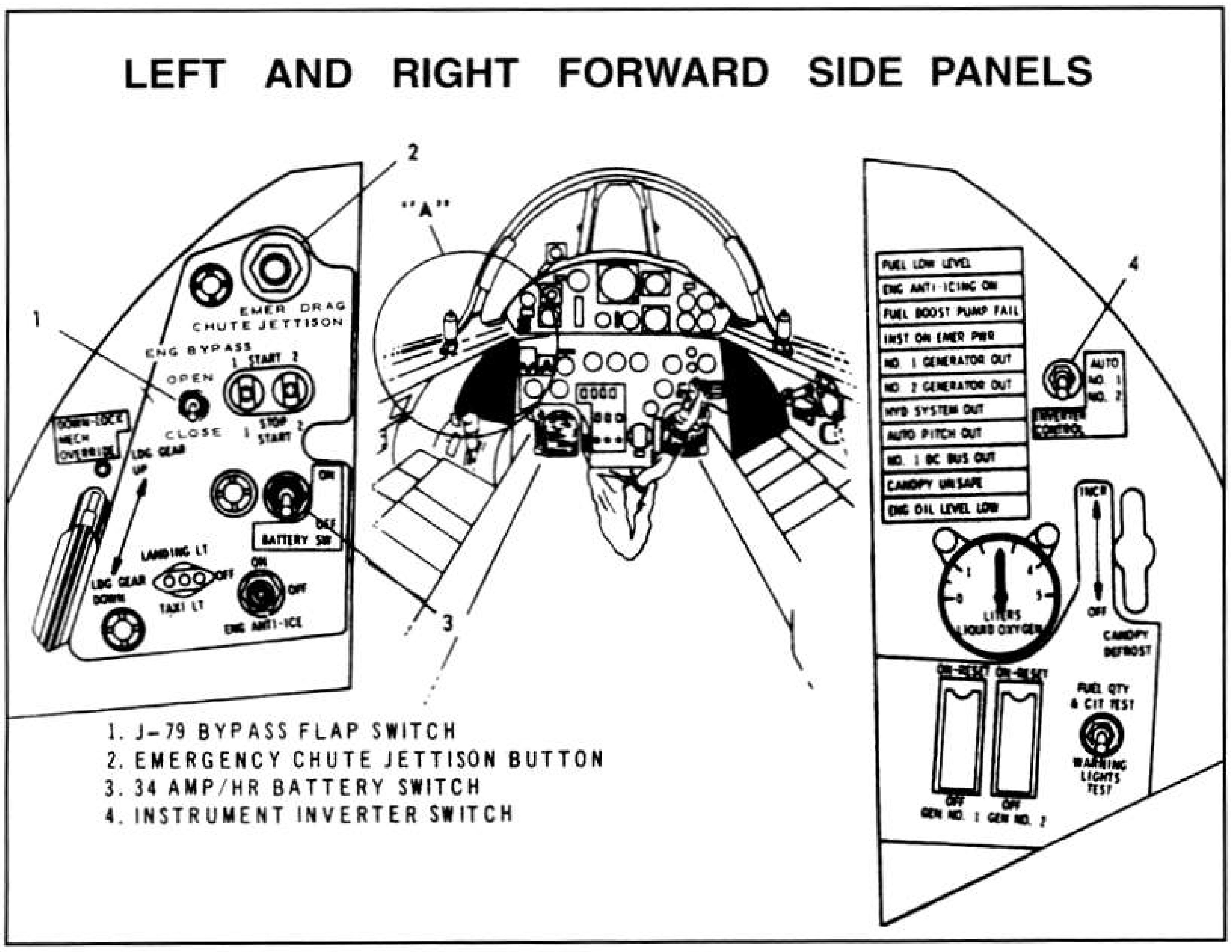
Housed in the nose section were four pairs of motors giving control on the pitch and yaw axis. Pitch control would be derived by firing the pair on top of the nose for nose down and likewise, the pair on the bottom of the nose would command nose up. Nose left or right (yaw) was then controlled by the motors on either the left, or right side of the nose. Roll control was a simpler setup with a single motor placed at the top of each wing tip and a single motor on the bottom. This pairing of motors in the nose provided a dual redundancy in the event a single motor failed. The remaining motor would take over and provide control. The four remaining motors in the wing tips also offered dual redundancy. Again, in the event of a single motor failure, the opposing motor on the opposite wing would be adequate to maintain roll control.

Pitchup is a common phenomenon experienced by most aircraft with T-tails. This phenomenon most generally occurs during high angles of attack, where a blanketing effect caused by the wing tends to "wash out" the tail surfaces, rendering them useless. With the tail surfaces ineffective, there is no pitch control, however the wing is still generating some lift. Pitchup results from this condition and usually leads to a spin. To counteract this on the AST, a RCS Kicker was installed. Similar to the aerodynamic kicker also installed on all stock F-104s, the RCS kicker would come in to play at altitudes where the dynamic pressure was too low for the aerodynamic system. Sensors installed on the aircraft would tell the kickers when the angle of attack was too great and that a pitchup was pending. The automatic response would either be a nose down command from the elevator for the aerodynamic system, or the pair of RCS motors on top of the nose would fire giving the nose down input, thus averting a pitchup.

Pilot control of the eight pitch/yaw and four roll RSC motors came via the RCS handle located on the left side of the forward instrument panel. This, too, was modeled after the controller used on the X-15. Control about all three axis was attained by rotating the handle fore/ aft, clockwise/counterclockwise and/or pushing it left or right. A pitch input would cause a single pitch motor, rated at 113lbs of thrust, to fire momentarily. The thrust of the RCS motors could not be modulated, so it was either full on or off. The yaw motors were identical in thrust output. Lateral (roll) movement was made possible by motors rated at 43lbs. The higher out-



**At right, the reaction controller was mounted on the left side of the instrument panel. (AFFTC/HO via Scott Libis)**



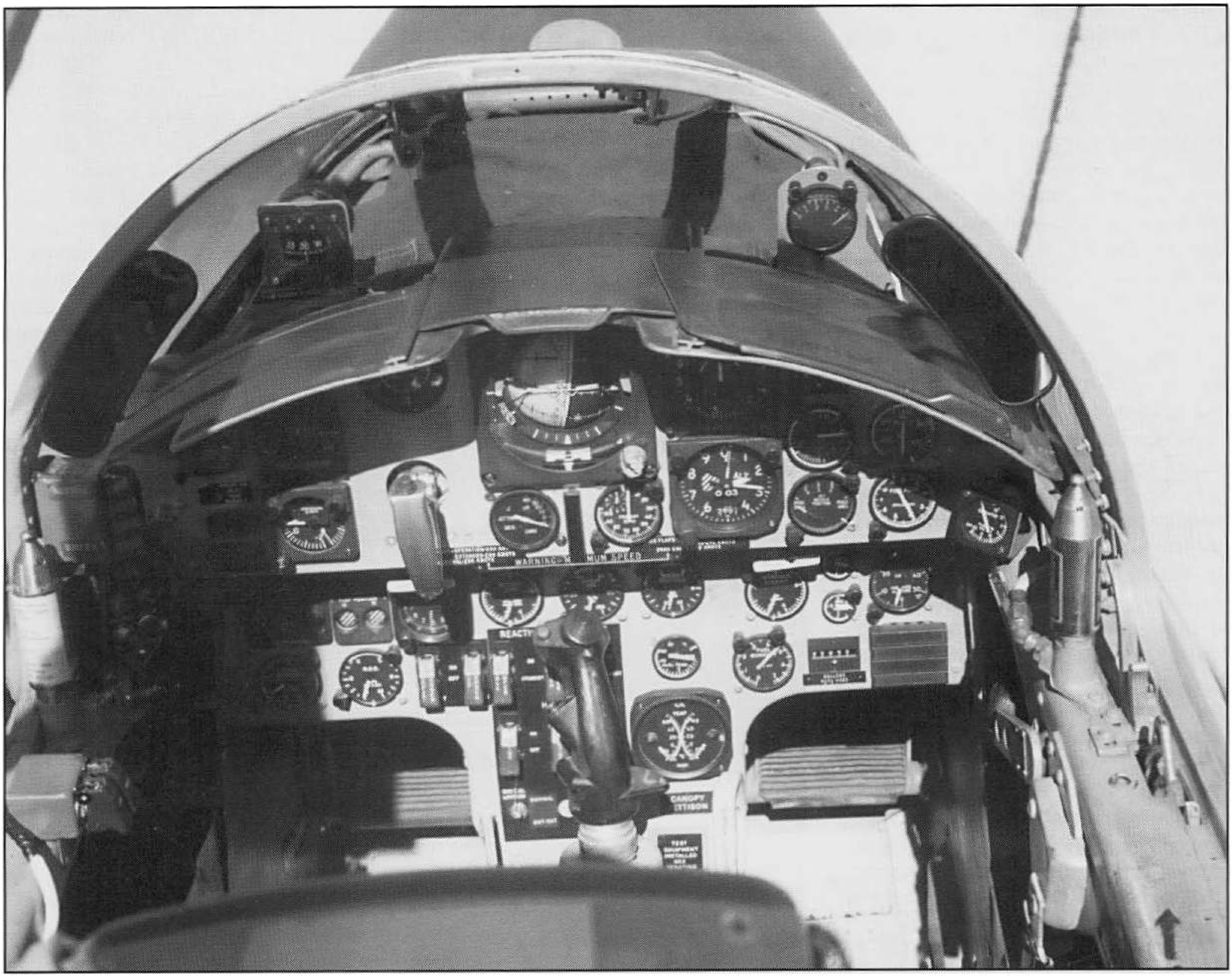
LEFT AND RIGHT FORWARD SIDE PANELS

1. J-79 BYPASS FLAP SWITCH
2. EMERGENCY CHUTE JETTISON BUTTON
3. 34 AMP/HR BATTERY SWITCH
4. INSTRUMENT INVERTER SWITCH

put motors were used for pitch and yaw because there was more inertia to overcome on these two axis.

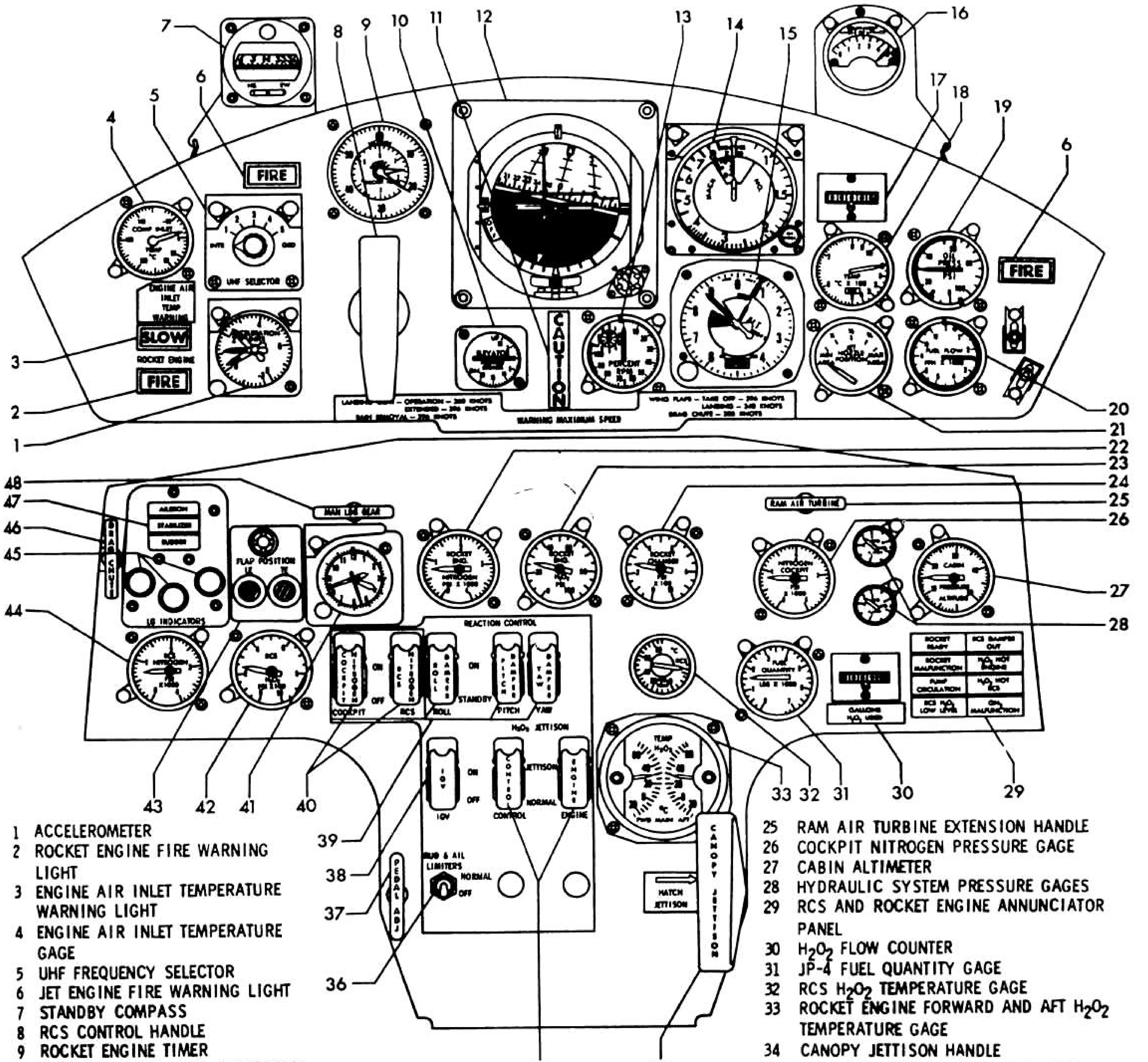
Internal workings of the RCS motors were basic. Hydrogen peroxide force-fed by gaseous nitrogen pressure enters the expansion nozzle of the rocket motor. Upon entering the expansion nozzle, the hydrogen peroxide would come in contact with a fine silver screen. The same chemical reaction that took place in the AR2-3 rocket engine would now happen here, causing the hydrogen peroxide to decompose and rapidly expand.

**Below, NF-104A pilot's instrument panel with the RCS to the left and below the turn-and-bank indicator. (Lockheed via Craig Kaston)**



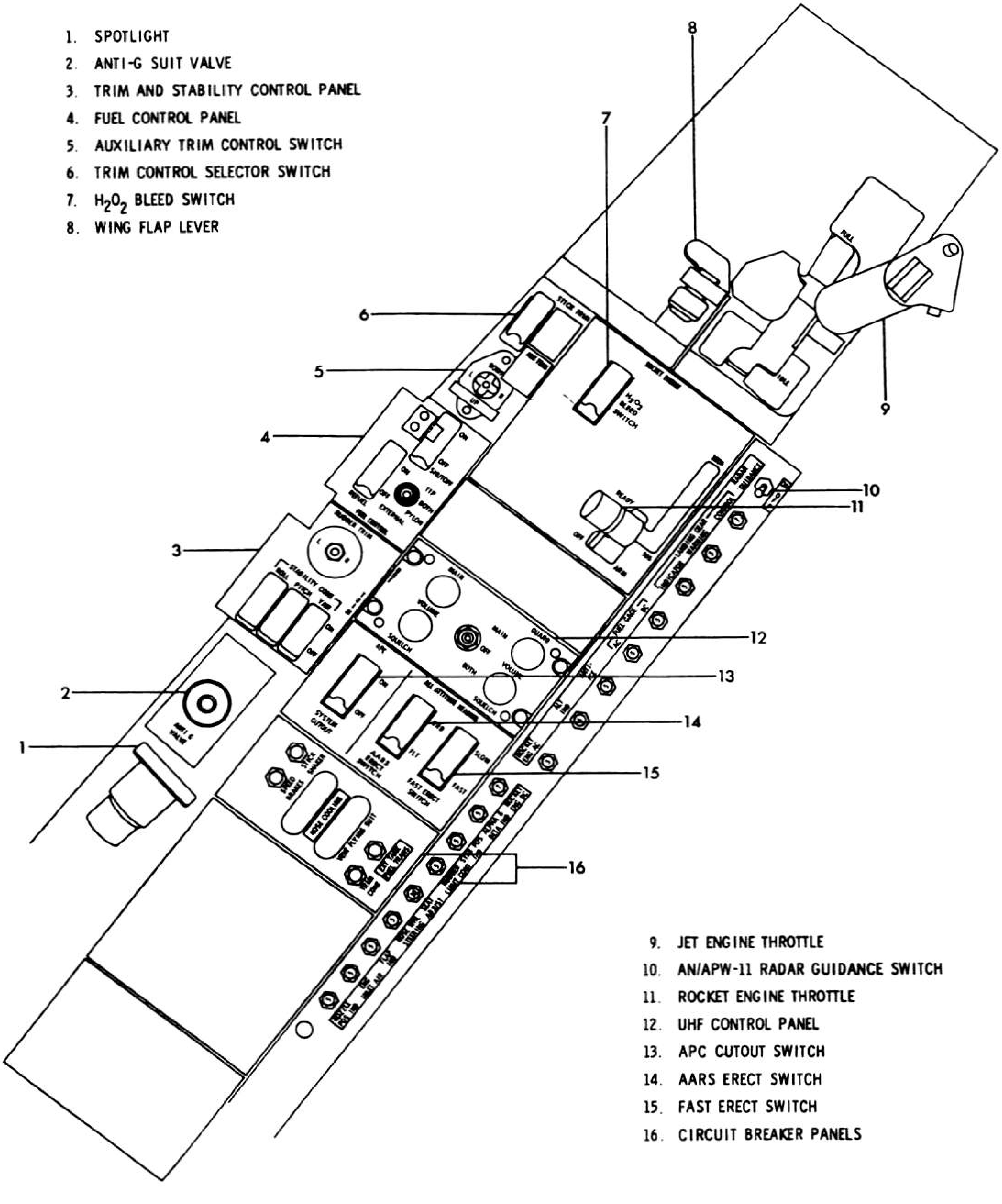
# NF-104A AEROSPACE TRAINER INSTRUMENT PANEL

## INSTRUMENT PANEL



1 ACCELEROMETER
2 ROCKET ENGINE FIRE WARNING LIGHT
3 ENGINE AIR INLET TEMPERATURE WARNING LIGHT
4 ENGINE AIR INLET TEMPERATURE GAGE
5 UHF FREQUENCY SELECTOR
6 JET ENGINE FIRE WARNING LIGHT
7 STANDBY COMPASS
8 RCS CONTROL HANDLE
9 ROCKET ENGINE TIMER
10 STABILIZER POSITION INDICATOR
11 CAUTION LIGHT
12 A11 ATTITUDE INDICATOR
13 JET ENGINE TACHOMETER
14 AIR SPEED INDICATOR
15 HIGH ALTITUDE ALTIMETER
16 AUTOPITCH CONTROL INDICATOR
17 CORRELATION COUNTER
18 EGT GAGE
19 OIL PRESSURE GAGE
20 FUEL FLOW INDICATOR
21 EXHAUST NOZZLE POSITION INDICATOR
22 ROCKET ENGINE NITROGEN PRESSURE GAGE
23 ROCKET ENGINE $H_2O_2$ PRESSURE GAGE
24 ROCKET CHAMBER PRESSURE GAGE
25 RAM AIR TURBINE EXTENSION HANDLE
26 COCKPIT NITROGEN PRESSURE GAGE
27 CABIN ALTIMETER
28 HYDRAULIC SYSTEM PRESSURE GAGES
29 RCS AND ROCKET ENGINE ANNUNCIATOR PANEL
30 $H_2O_2$ FLOW COUNTER
31 JP-4 FUEL QUANTITY GAGE
32 RCS $H_2O_2$ TEMPERATURE GAGE
33 ROCKET ENGINE FORWARD AND AFT $H_2O_2$ TEMPERATURE GAGE
34 CANOPY JETTISON HANDLE
35 RCS AND ROCKET ENGINE $H_2O_2$ JETTISON SWITCHES
36 RUDDER AND AILERON LIMITER SWITCH
37 RUDDER PEDAL ADJUSTMENT HANDLE
38 IGV SWITCH
39 RCS STABILITY CONTROL SWITCHES
40 RCS AND COCKPIT NITROGEN SWITCHES
41 CLOCK
42 RCS $H_2O_2$ PRESSURE GAGE
43 WING FLAP POSITION INDICATORS
44 RCS NITROGEN PRESSURE GAGE
45 LANDING GEAR POSITION INDICATOR LIGHTS
46 DRAG CHUTE HANDLE
47 AILERON, STABILIZER, AND RUDDER TAKEOFF TRIM INDICATOR LIGHTS
48 MANUAL LANDING GEAR RELEASE HANDLE

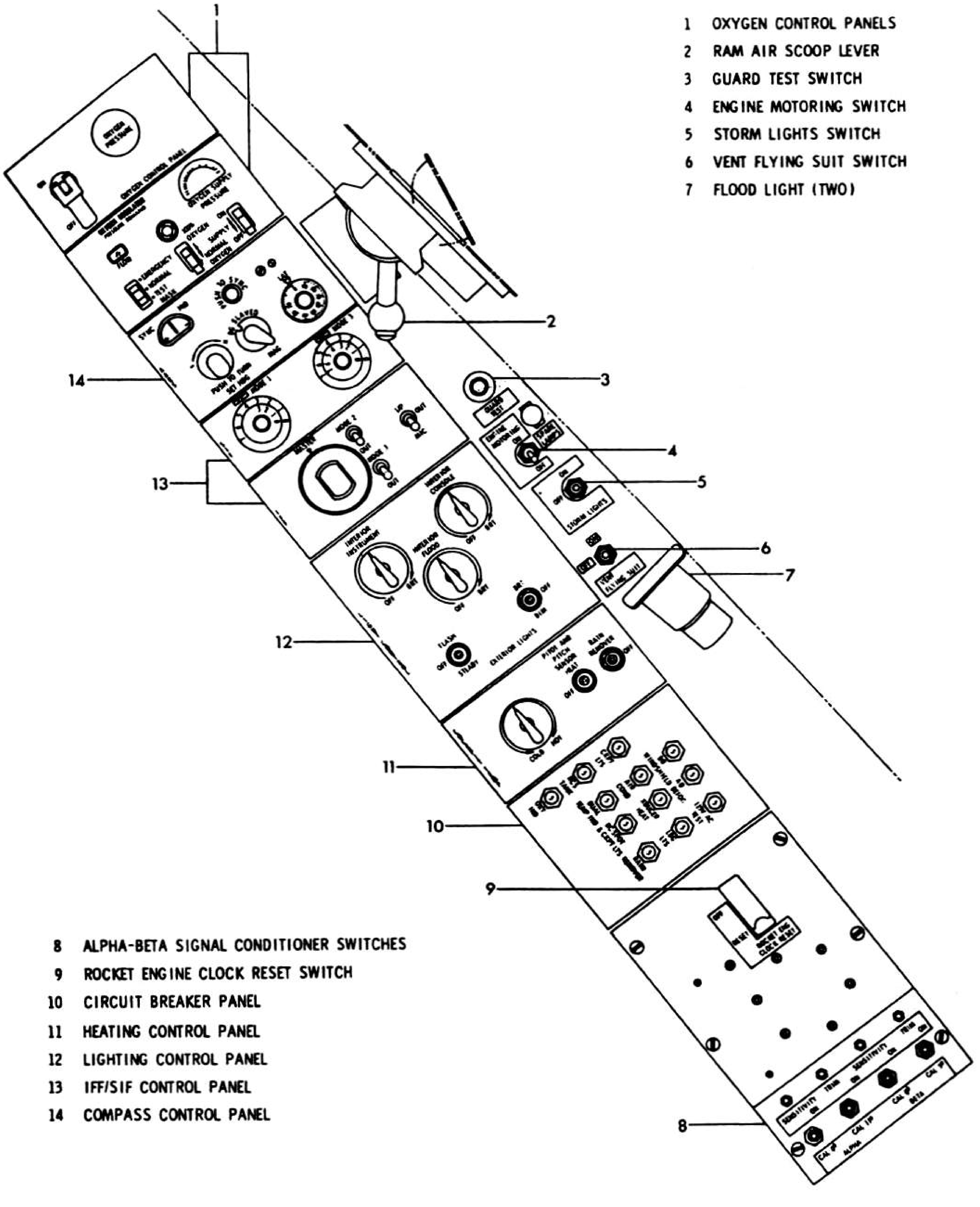
# LEFT - HAND PILOT'S CONSOLE



1. SPOTLIGHT
2. ANTI-G SUIT VALVE
3. TRIM AND STABILITY CONTROL PANEL
4. FUEL CONTROL PANEL
5. AUXILIARY TRIM CONTROL SWITCH
6. TRIM CONTROL SELECTOR SWITCH
7. $H_2O_2$ BLEED SWITCH
8. WING FLAP LEVER

9. JET ENGINE THROTTLE
10. AN/APW-11 RADAR GUIDANCE SWITCH
11. ROCKET ENGINE THROTTLE
12. UHF CONTROL PANEL
13. APC CUTOUT SWITCH
14. AARS ERECT SWITCH
15. FAST ERECT SWITCH
16. CIRCUIT BREAKER PANELS

# RIGHT - HAND PILOT'S CONSOLE

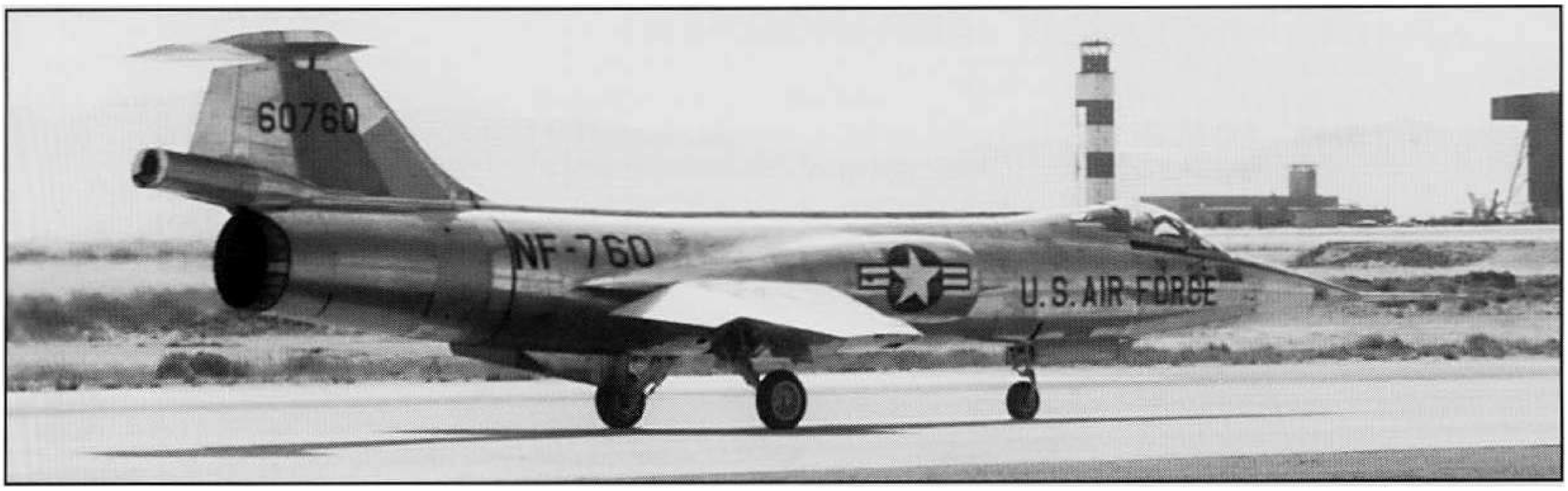


1 OXYGEN CONTROL PANELS
2 RAM AIR SCOOP LEVER
3 GUARD TEST SWITCH
4 ENGINE MOTORING SWITCH
5 STORM LIGHTS SWITCH
6 VENT FLYING SUIT SWITCH
7 FLOOD LIGHT (TWO)

8 ALPHA-BETA SIGNAL CONDITIONER SWITCHES
9 ROCKET ENGINE CLOCK RESET SWITCH
10 CIRCUIT BREAKER PANEL
11 HEATING CONTROL PANEL
12 LIGHTING CONTROL PANEL
13 IFF/SIF CONTROL PANEL
14 COMPASS CONTROL PANEL

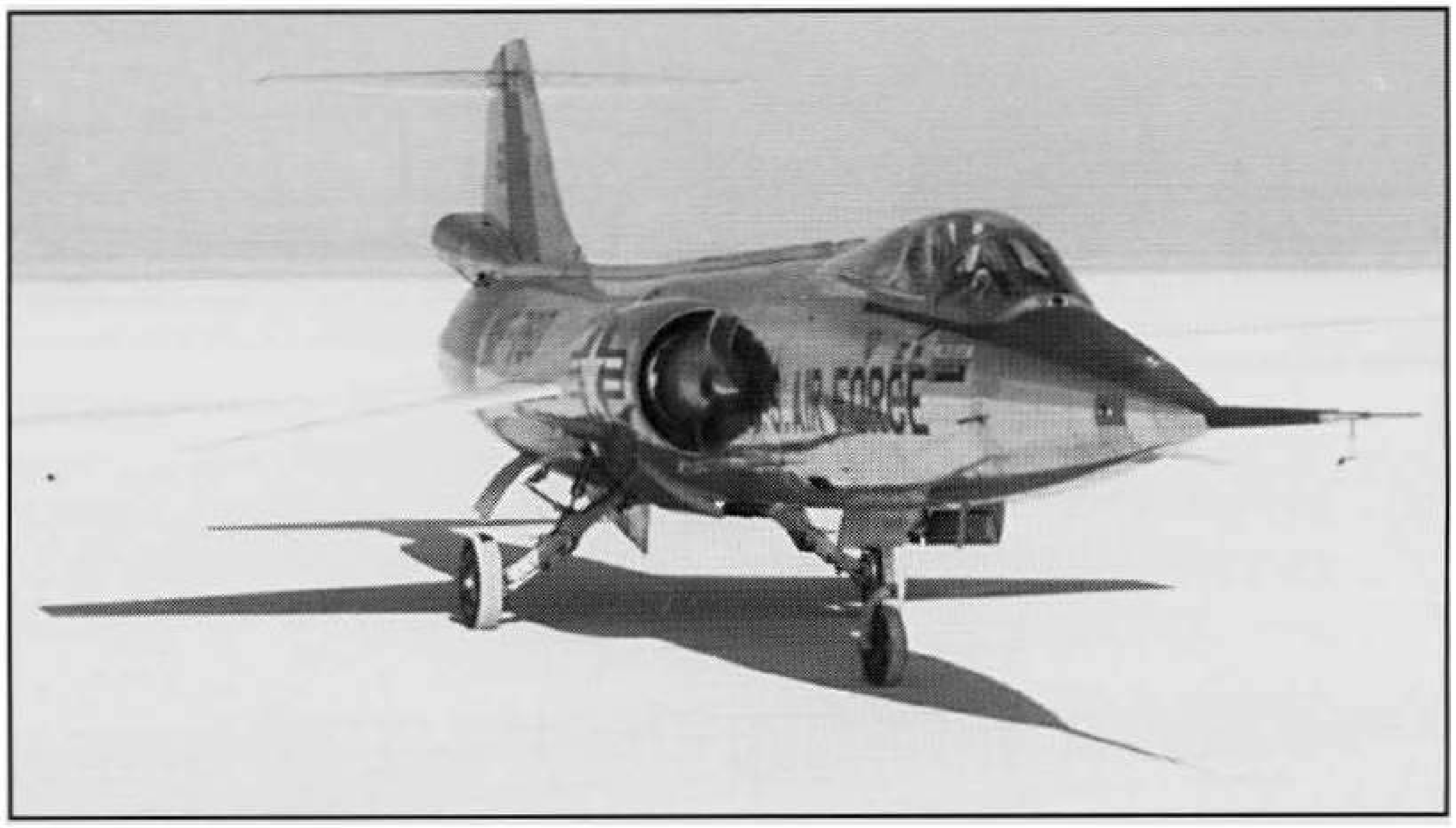
60756
NF-756
U.S. AIR FORCE
USAF

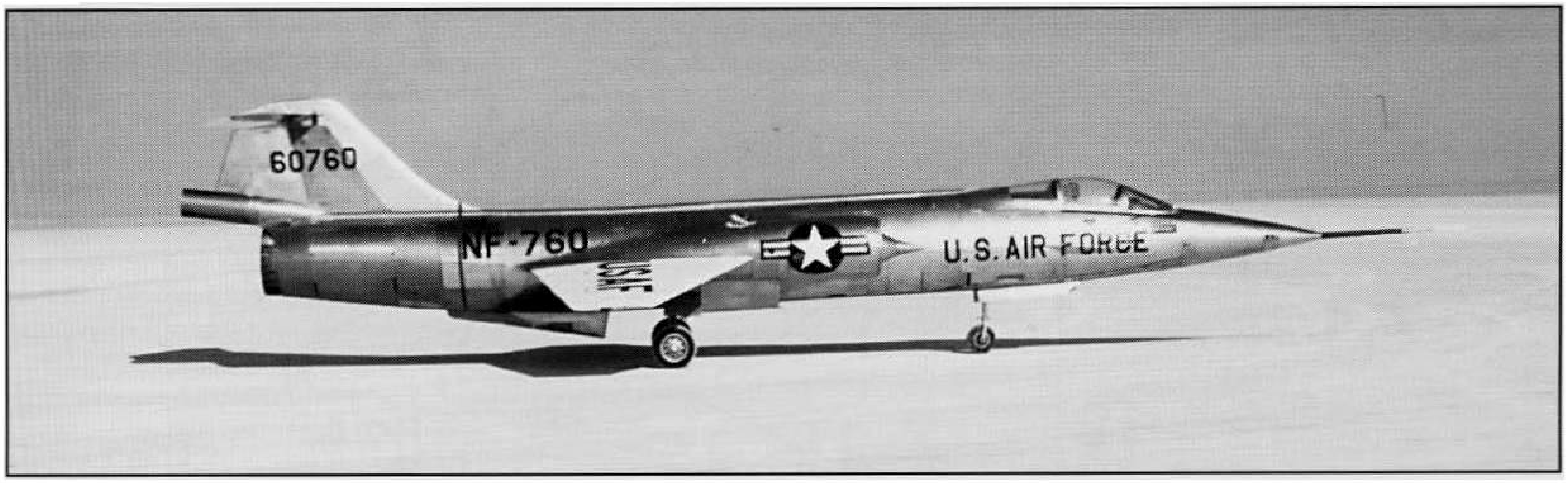
U.S. AIR FORCE
NF-756
60756

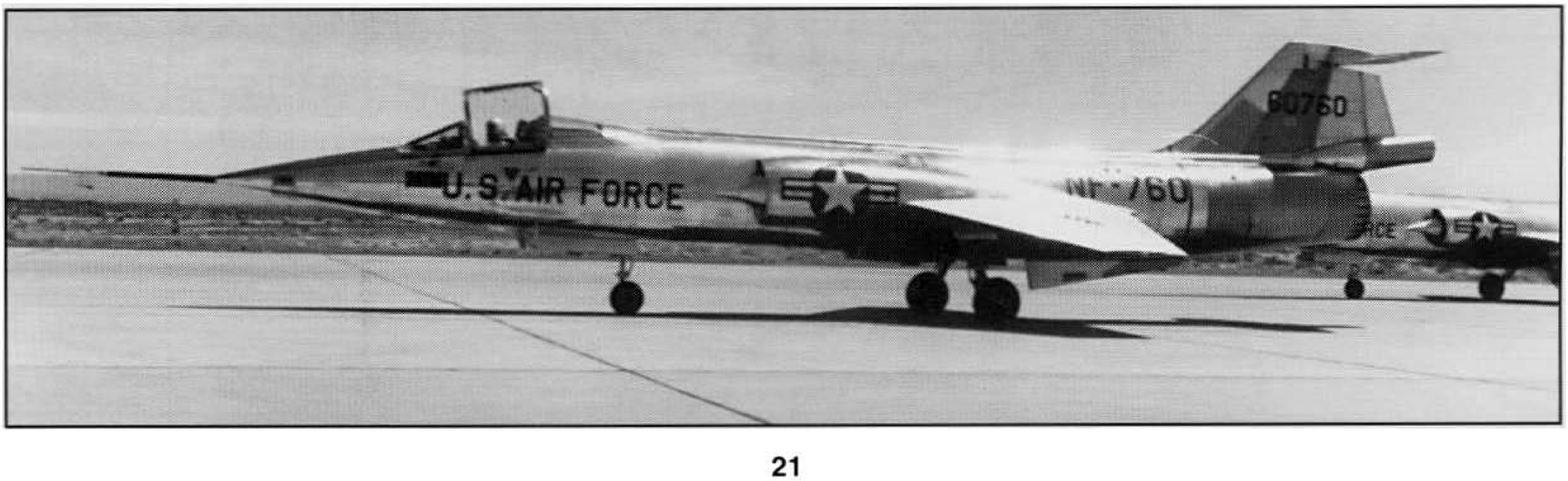


## NF-104A GALLERY

Above left, 756 under tow after the annual open house at Edwards AFB on 5-16-64. Note the open engine access door aft of the main gear. (William Swisher) At left, 756 in a classic zoom climb profile. (via Tony Landis) Above, 760 taxing in with Robert Smith at the controls in November 1963. (USAF via Craig Kaston) At right and below, 760 sits on the lake bed on 2-4-65. (USAF via Scott Libis & Craig Kaston) Bottom, 760 taxing out for an air show fly-by at Edwards AFB on 16 May 1964 with 756 in the background. (William Swisher)





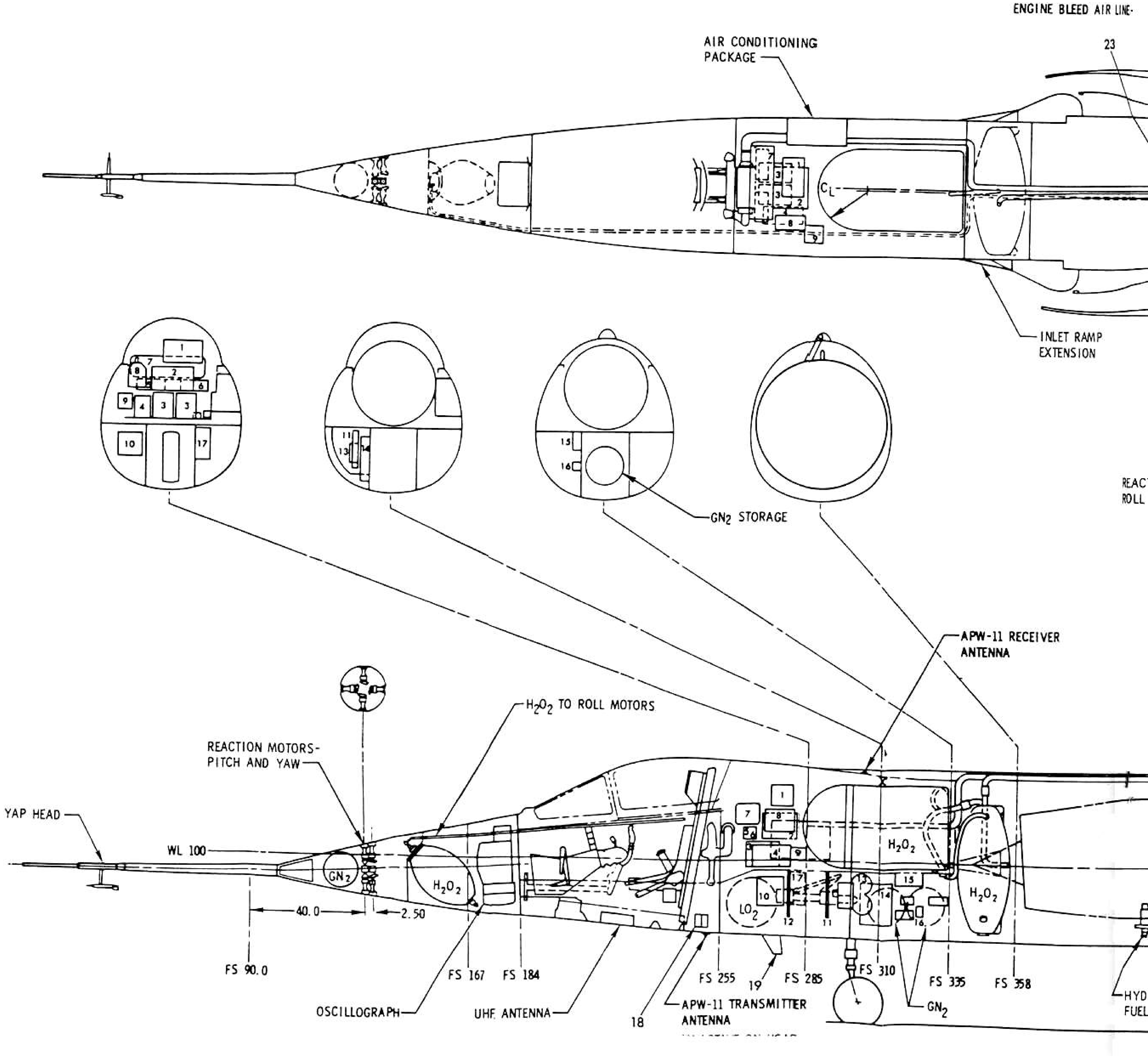


# NF-104A INTERIOR ARRANGEMENT

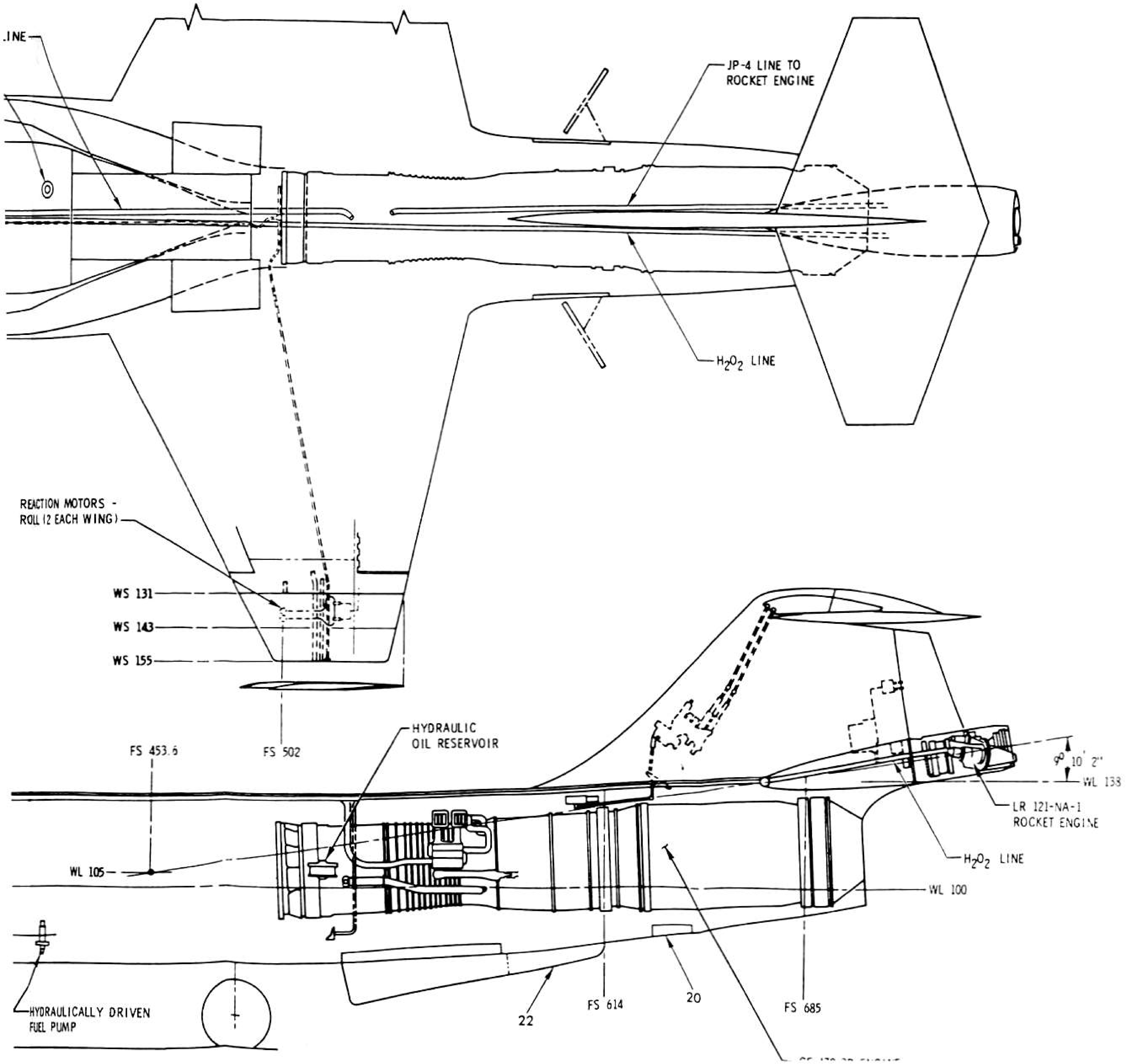
## 1/48 SCALE

**ELECTRONIC EQUIPMENT:**

1.) APX-46 (REC-XMTR)
2.) APW-11 (REC-XMTR)
3.) 750 VA Inverter
4.) Lear 3 Axis Platform



5.) Lear Compass Adapter
6.) Lear Amplifier Power Supply
7.) "E" Compartment Junction Box
8.) 3 Axis Damper
9.) APW-11 Dynamotor
10.) 34 AMP HP Battery
11.) Automatic Observer Panel
12.) Automatic Observer Panel Mirror
13.) Camera
14.) Instrument Junction Box
15.) Reaction Damper
16.) Instrumentation - Including Rate Gyros, 2 Axis Gyro, Intervalometer Flowmeter and Converters
17.) 200 AMP TR Unit
18.) UHF (REC - XMTRS)
19.) UHF Antenna (56-760 only)
20.) Drag Chute Compartment
21.) RCS Kicker
22.) APX-46 Antenna
23.) Fuel Vent - G Relief Valve



## ZOOM MANEUVER

Only the top students in each aerospace class would be selected to fly the AST. A flight would be made in a standard F-104 with a full pressure suit to familiarize the student. With the suit fully inflated, the student would become used to the restricted movements imposed by the suit. The next flight would be with an instructor in a two-place F-104, where the student would make a trial run of the zoom profile and gain experience with the extensive checklist. Before a solo zoom mission, the student would be required to spend four hours in a ground simulator for further preparation. Upon completion of the simulator, the student would then go on to three solo flights in an F-104 where there would be a gradual build-up in climb angles. A two-place '104 would chase the student, with the backseater dedicated to coaching the student through the profile checklist. First flight climb angle was held to 30 degrees, with gradual increases on subsequent flights to 40 and 45 degrees. These 30-minute flights passed so quickly that the students hardly noticed the passage of time. Next came a four hour ground school on the AST, which would then be followed by the AST flights.

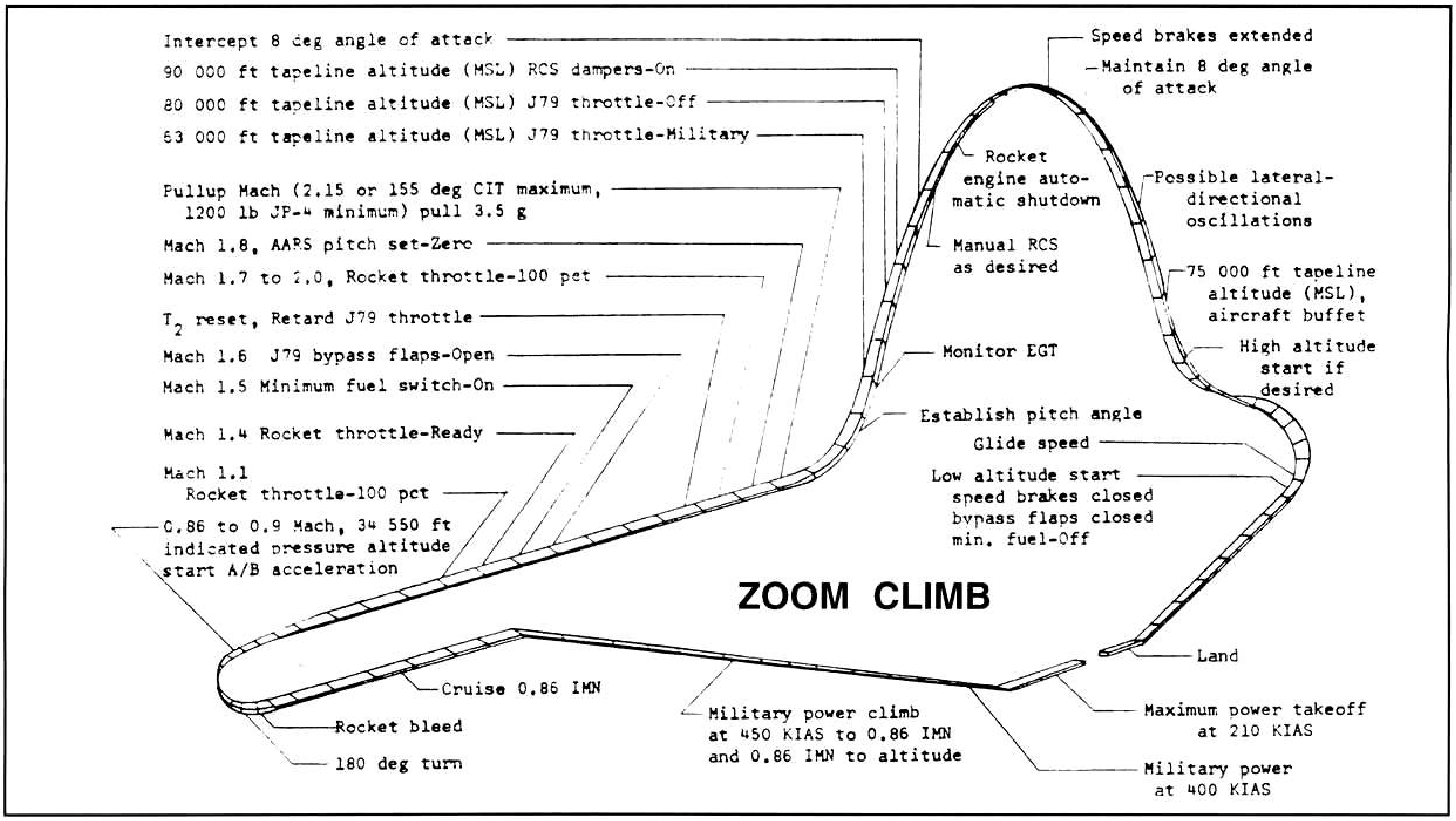
Air Force Technical Order T.O. 1F-104A-1-2 gives the following description of the Zoom Maneuver:

### Acceleration

Supersonic acceleration is slower in the AST than the standard F-104A. Each step in the acceleration checklist is necessary for a safe zoom mission, therefore, the in-flight checklist should be carefully followed. For example, failure to reset AARS pitch to zero could result in an excessive pitch angle and subsequent flight outside the safe operating envelope. When the rocket throttle is moved from READY to 100% for rocket ignition, the $H_2O_2$ tank pressure will fall below its static pressure, sometimes as low as 38 psi. As the rocket fires, the tank pressure must rise to a value between 40 and 65 psi depending on the particular regulator. Generally, this pressure will be approximately 43 psi. A very slight noseup pitch change accompanies rocket engine ignition. This pitching is barely discernible. After rocket engine ignition, the CAUTION light will be on due to illumination of these annunciator lights: FUEL LOW LEVEL (below approximately 1500 lb), ROCKET READY, RCS DAMPER OUT, and PUMP CIRCULATION. During the zoom climb the FUEL BOOST PUMP light will illuminate if the forward pumps (No. 1 and No. 2) are uncovered and the ROCKET MALFUNCTION light will indicate normal automatic shutdown of the rocket engine due to $H_2O_2$ depletion. Shutdown will be accompanied by noticeable thrust surges. Distances traveled during the acceleration and zoom should be carefully computed (see appendix) so that reentry is completed near the landing area should air start be unsuccessful. Pullup Mach number is very important in order to obtain the desired performance.

### Pullup

A 3.5 g pullup is initiated at the Mach number determined by preflight planning (never exceed 2.15 IMN or 155 degrees C CIT whichever occurs first). Alternate (lower) pitch angles should be preplanned in the event a pullup at lower Mach number is required. This could occur as a result of reaching minimum fuel level (1200


Intercept 8 deg angle of attack
90 000 ft tapeline altitude (MSL) RCS dampers-On
80 000 ft tapeline altitude (MSL) J79 throttle-Off
63 000 ft tapeline altitude (MSL) J79 throttle-Military
Pullup Mach (2.15 or 155 deg CIT maximum, 1200 lb JP-4 minimum) pull 3.5 g
Mach 1.8, AARS pitch set-Zero
Mach 1.7 to 2.0, Rocket throttle-100 pct
$T_2$ reset, Retard J79 throttle
Mach 1.6 J79 bypass flaps-Open
Mach 1.5 Minimum fuel switch-On
Mach 1.4 Rocket throttle-Ready
Mach 1.1 Rocket throttle-100 pct
0.86 to 0.9 Mach, 34 550 ft indicated pressure altitude start A/B acceleration
Cruise 0.86 IMN
Rocket bleed
180 deg turn
Military power climb at 450 KIAS to 0.86 IMN and 0.86 IMN to altitude
Speed brakes extended
Maintain 8 deg angle of attack
Rocket engine automatic shutdown
Manual RCS as desired
Possible lateral-directional oscillations
75 000 ft tapeline altitude (MSL), aircraft buffet
Monitor EGT
High altitude start if desired
Establish pitch angle
Glide speed
Low altitude start speed brakes closed bypass flaps closed min. fuel-Off
ZOOM CLIMB
Land
Maximum power takeoff at 210 KIAS
Military power at 400 KIAS

lb), compressor stalls, arrival at the pullup point prior to obtaining the desired Mach number, reaching the CIT limit, etc. The pullup is entered at a rate of about 1g per second. During the pullup and throughout the remainder of the zoom maneuver the wings should remain level and the roll rate should be held as near zero as possible. Mild transient lateral and directional oscillations may occur during the pullup and climb but should subside quickly. The pullup is discontinued upon reaching the desired pitch angle. The maximum pitch angle is 50 degrees indicated *(authors note: 50 degrees reflects the post-Yeager accident restriction)*. This maximum must be reduced as a result of pullup Mach variations and wind and temperature variations at 35,000 feet in order to remain over the 20 psf minimum q limit. Each zoom must be carefully planned using existing weather data to ensure a flight within the operating envelope, which includes supersonic speed throughout the zoom.

### Climb

One of the more important performance parameters controlled by the pilot is the pitch angle. Maintaining the proper angle throughout the climb is necessary to obtain desired performance. Though this is primary, other pilot functions can not be overlooked. EGT should be carefully monitored and throttle reduction may be required to maintain it within limits. Once the temperature starts to increase, the rise is rapid. The throttle should be moved to MILITARY whenever the temperature reaches 625 degrees C. Do not exceed 63,000 feet with the throttle in afterburner range. The throttle should then be moved to OFF at 610 degrees C or 80,000 feet, whichever occurs first. The pitch angle is held constant until "over-the-top" angle of attack is reached. As this point is approached, the alpha bar will slowly descend until it reaches the miniature airplane of the AARS. At this point the aim angle of attack has been attained and is maintained by "flying" the airplane toward the alpha bar just as the ILS glide slope is flown. As attitude increases with a corresponding decrease in dynamic pressure (q), yaw-roll aerodynamic coupling along with yaw-pitch gyroscopic coupling will become more apparent. In order to decrease drag losses and gain maximum pilot proficiency, the angle of attack should be maintained as nearly constant as possible and the sideslip and roll angles held near zero. The beta or sideslip bar moves toward the direction of sideslip and corrections can be likened to "flying" the miniature airplane toward the bar as is done in tracking the ILS localizer. Unlike the ILS, the corrections toward the beta bar are made solely with the rudder or RCS yaw control.

Within its operating limits the airplane can be controlled with aerodynamic controls. The RCS is effective only in the low q region about 90,000 feet. RCS control is non-proportional and therefore requires very short duration bursts for smooth attitude control. Extended RCS inputs will not only cause overcontrol in the plane of correction, but set up excessive motion in the other primary planes. For example, a nosedown motion creates gyroscopic right sideslip which could in turn induce roll. Should controllability ever become questionable during RCS use, a return to the more familiar aerodynamic controls is recommended. Aerodynamic control power is sufficient to stop reasonable oscillations within the q limit. A case in point is the simultaneous actuation of the RCS and the APC kickers. In this case the angle of attack falls from 15 degrees to about zero degrees in approximately 2 seconds. A rapid noseup cycle follows which can be stopped with forward movement of the control stick.

### WARNING

**Large nosedown control inputs should not be applied during the nosedown motion resulting from kicker actuation. Such action could result in extreme pitch rates and subsequent loss of control. If kicker actuation occurs during low q operations, the pilot should slightly reduce back pressure during the nosedown motion, then apply forward stick as required to stop the subsequent noseup motion. If necessary, nosedown RCS inputs can be used in conjunction with aero controls.**

RCS dampening is not mandatory. In order to preserve the RCS $H_2O_2$, dampers should not be engaged below 90,000 feet. Use of RCS damping simplifies RCS manual control by decreasing excursions of the plane, especially in sideslip.

### Reentry

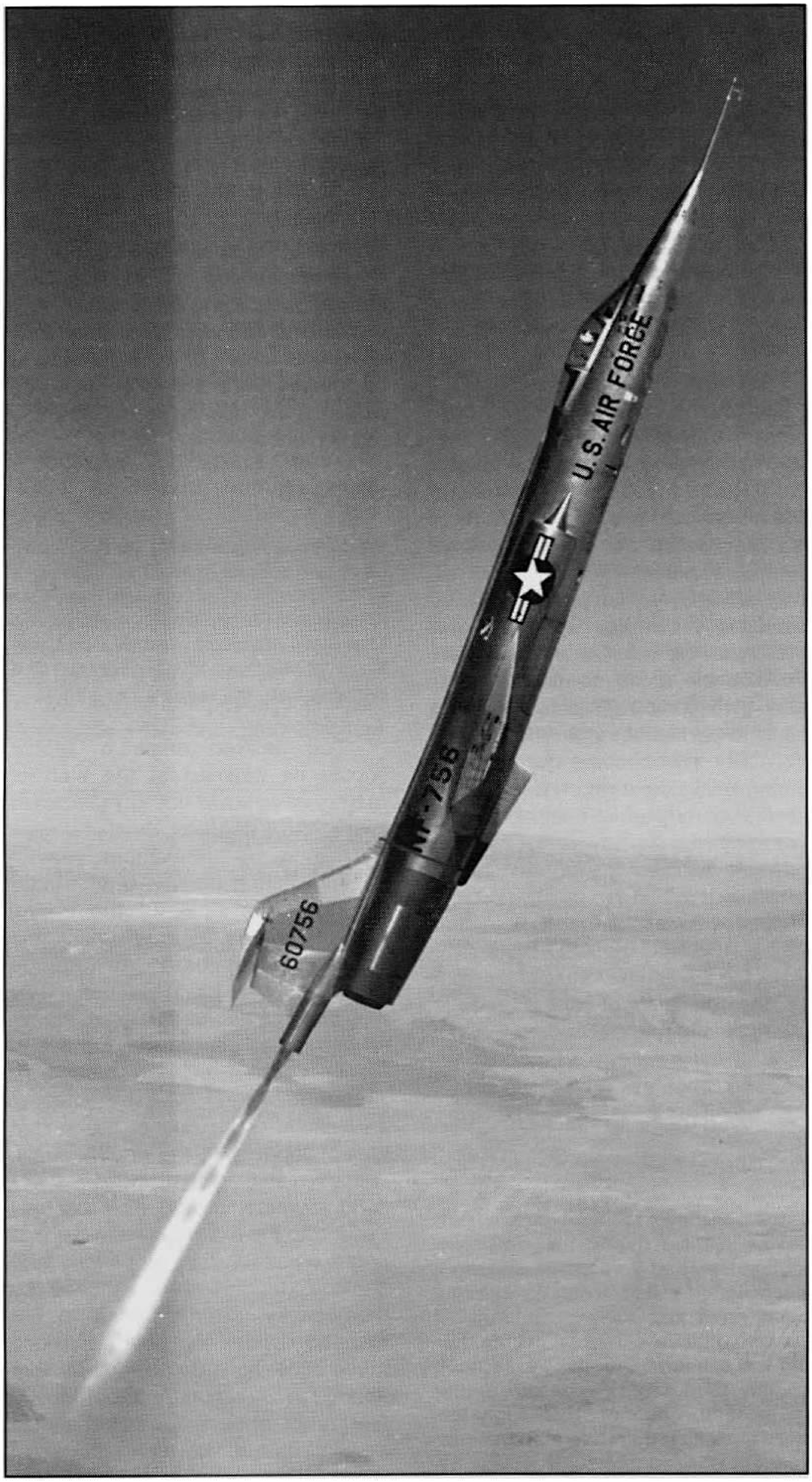
Reentry may be made without extending the speed brakes, however, speed buildup will be increased, thereby magnifying the cockpit heat, oscillations and vibrations which may be encountered. Since nothing is to be gained with the speed brakes closed, their use on all reentries is recommended.

### WARNING

**Continuous requirement for nosedown pitch corrections in order to maintain 8 or 11 degrees alpha nearing the zoom peak indicates operation outside the safe flight envelope. In this event, the angle of attack should be lowered to 5 degrees until the reentry has begun.**

The desired angle of attack should be attained at the start of reentry and should not be maintained lower than 8 degrees. Smaller angles will increase maximum speed attained during reentry. Shortly after departing the peak of the zoom, Stability increases and noticeable coupling disappears. As altitude decreases, high Mach number effects may become apparent. These appear as undamped oscillations, but are in reality due to the J79 being off. Apparently the lateral-directional oscillations occur due to the limited airflow capacity of the engine ducts, causing a shifting of shock waves creating asymmetric drag. This will only occur with the high Mach number and angle of attack (see appendix) and can be decreased or stopped by momentarily lowering alpha to 6-8 degrees. Under identical conditions these oscillations do not appear with the J79 in operation. At about 75,000 feet, moderate airplane buffet should be anticipated. Lowering angle of attack decreases this. However, the

**Below, NF-104A** 60-756, **climbing at close to 70° climb angle during a zoom climb over the Mojave desert. (AFFTC/HO via Scott Libis)**

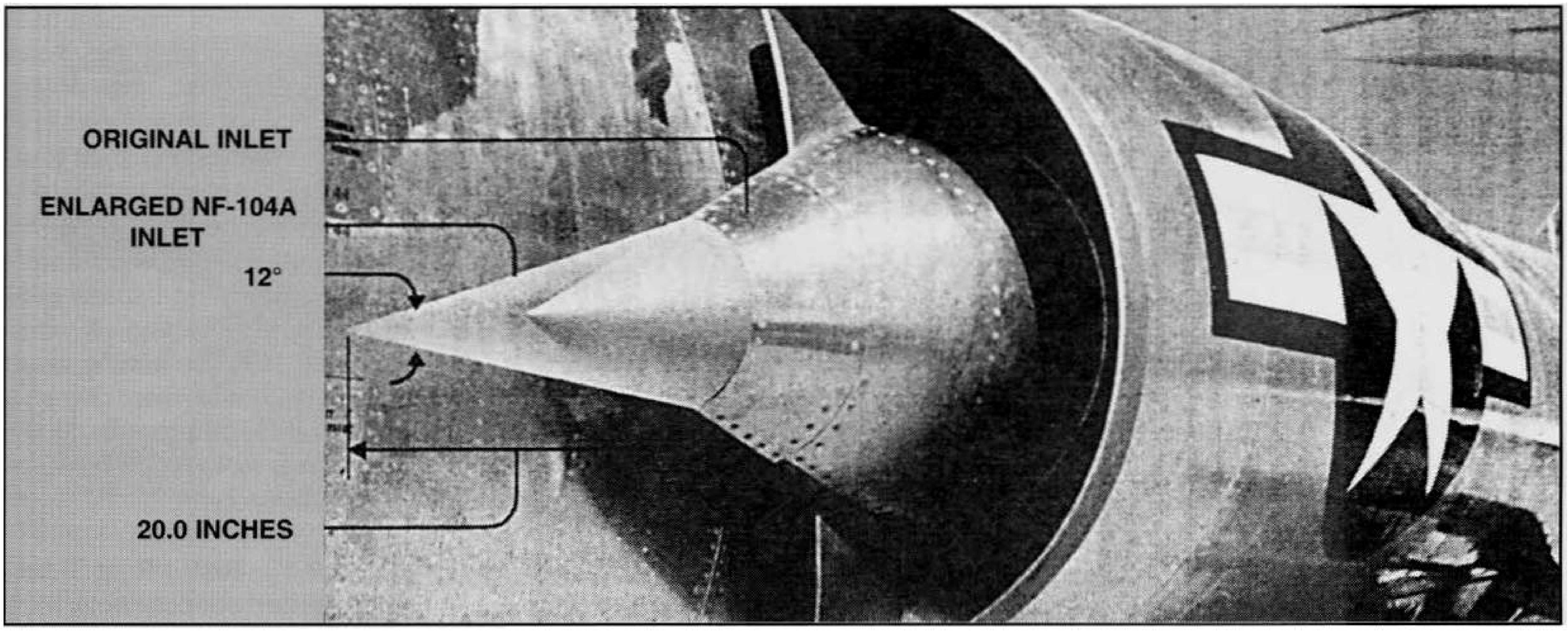


pullout altitude is lowered. If reentry is properly executed, the airplane g limits will not be approached. So long as the g limits are respected, the buffet may be ignored. Near 60,000 feet, the rumbling first noticed when the engine bypass flaps were opened at 1.6 Mach in the acceleration may reappear. This will diminish if the bypass flaps are closed, however, this is not necessary. Should the distance to the landing area be excessive, a turn may be started at 65,000 feet by rolling 30 degrees while maintaining reentry angle of attack. The turning rate will be very low at this altitude. Altitude for completion of pullout will vary between 40,000 and 55,000 feet, depending on the profile. Reentry Mach numbers greater than 2.1 with speed brakes retracted and 2.0 with brakes extended have been reached without adverse effects. High cockpit temperatures are a result of high speed flight without the J79 engine operating.

Engine air starts have been successfully initiated as high as 75,000 feet with the minimum fuel switch ON. Recommended air start procedures should be followed. In case of a high altitude start during reentry, the start can be made with bypass flaps open. A glide with wing flaps up should be established in accordance with the data contained in the appendix.

## Landing

After a zoom mission, the aircraft center of gravity will be near 20 percent MAC with the rocket $H_2O_2$ expended. Normal landing procedures should be followed except that the nose gear may be held off to 120 knots to minimize nose gear wear. Do not allow nose to drop abruptly. This procedure is not recommended for minimum landing distance, and normal F-104 procedures should be followed where the runway available is critical. Do not deploy the drag chute with the nose gear raised. After touchdown, with takeoff flaps extended (except dead stick), landing flaps may be lowered to increase drag and decrease brake wear. If landing is necessary with heavy gross weight, airspeed adjustments should be made in accordance with T.O. 1F-104A-1. One gallon of $H_2O_2$ weighs approximately 11.5 pounds. (Add 2600 pounds to fuel remaining for



weight correction with full $H_2O_2$ load.)

## WARNING

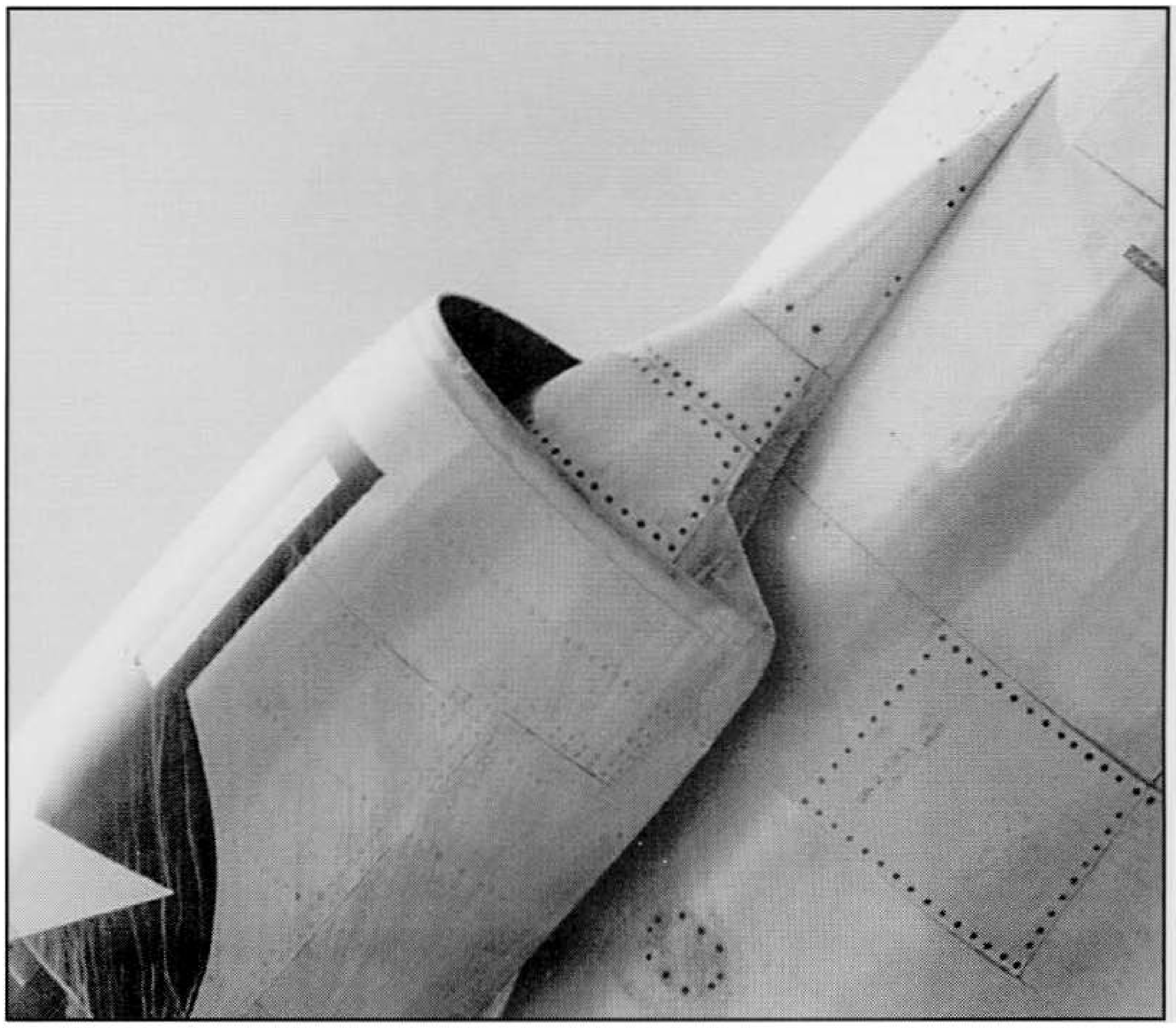
**Stabilizer power decreases with a gross weight increase. A steep approach should not be made when landing in a heavy weight condition. (Refer to section V for the center of gravity limitations.)**

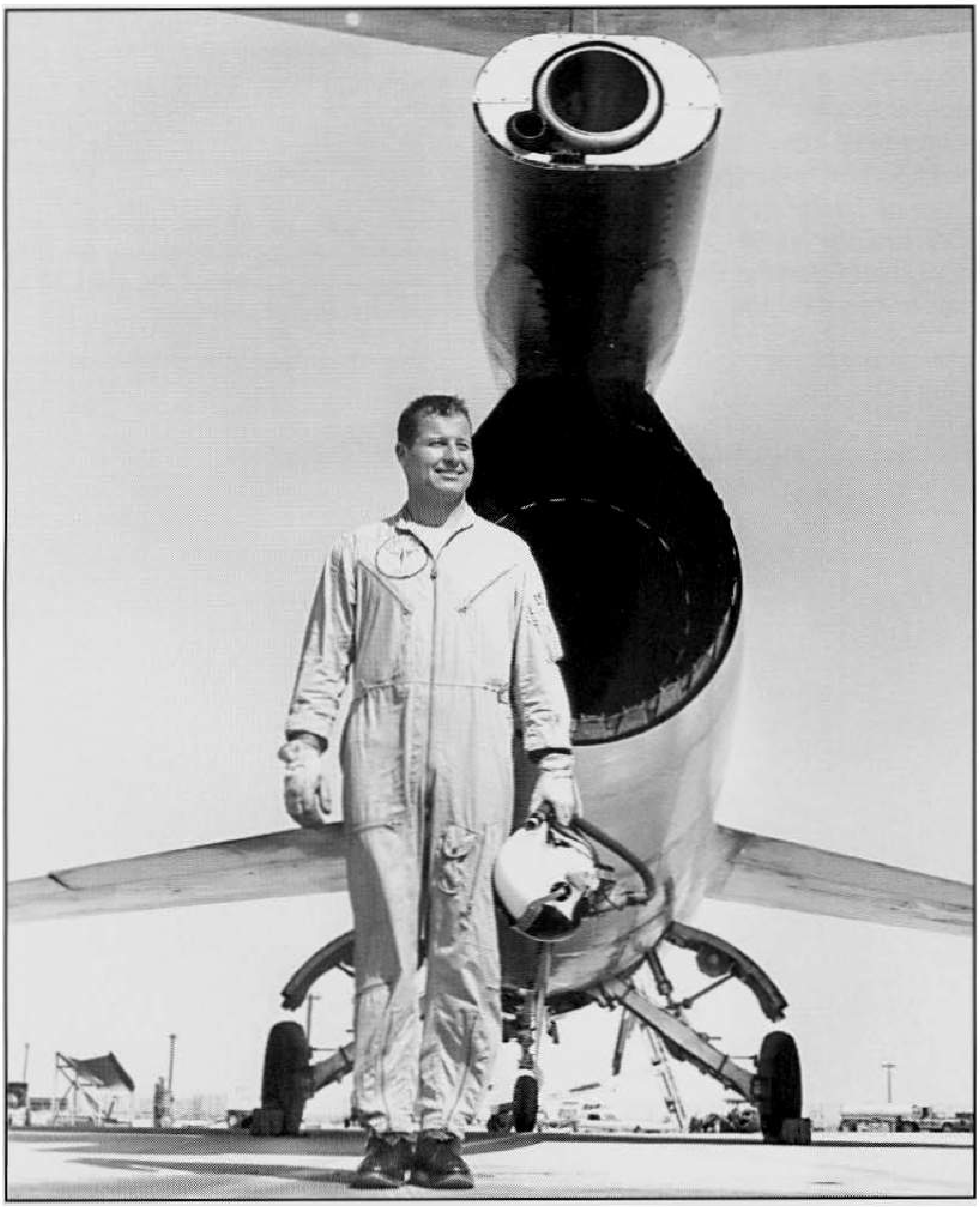
## FLIGHT TEST

Lockheed conducted a limited category I test program that was run throughout 1963 before the three aircraft were delivered to the Air Force. Lockheed Flight Test Analyst Engineer, David Gill, participated in the initial contractor flight test program conducted at Air Force Plant 42 in Palmdale, California. "My job on the program was to participate in performance, flying qualities and propulsion testing of the J79 turbojet engine and AR2-3 rocket engine. The Aerospace Trainer's primary engine was the General Electric J79. This engine was a leap forward in turbojet technology at that time and gave the '104 Mach 2 plus performance. However, the engine inlet cone had been designed to optimize engine performance up to Mach 2 only. We were faced with a new challenge, the Aerospace Trainer's mission flight plan called for Mach 2.2 speeds and an altitude envelope of over 100,000 feet."

"Lockheed had to go back to the drawing board and redesign the inlet cone. The purpose of the original cone was to generate a shock wave when the aircraft neared supersonic speed. The shock wave would impinge on the lip of the inlet and this in turn would slow down the supersonic airflow. After slowing the air to subsonic speeds, it was then allowed to continue down the inlet duct. This is important, because a turbojet can't operate with supersonic airflow. Compressor stalls and other nasty things like that happen. Lockheed's answer to this new mission requirements was simply to extend the length of the inlet cone another 20 inches. Another series of shock waves would result from this extension, slowing the Mach 2.2 air to 2.0 where the original design would recognize and take over to complete the job."

**Below, close up of the extended inlet cone that was installed on the NF-104s to reduce the speed of the inlet air to subsonic. (Scott Libis)**





"Another point of concern was engine over-temp during the zoom climb. At 63,000 feet, the engine power setting would be reduced from afterburner to military and then to off at 70,000 feet. Again, to optimize engine performance under various conditions, a series of inlet flaps were rescheduled, restricting bypass cooling air to the turbine section. A reduction of cooling air to the turbine would cause it to get hotter than sin, so it was necessary to retard the throttle and monitor the exhaust gas temperature during the zoom."

"Lockheed Test Pilot Jack Woodman started our contractor flight test program on July 9, 1963, when he took NF-104 #762 up for the first time. Woodman came to us in 1962 from the Royal Canadian Air Force where he flew F-104s and was one of the privileged few to pilot the Avro Arrow. One month later he began the rocket augmented flights in the NF-104. In all, contractor testing out of Palmdale was wrapped up in 50 flights."

"The one episode that stands out in my mind regarding the flight testing of these aircraft involved # 756 on October 23, 1963. On this particular flight, which had just peaked at 118,000 feet, Woodman commanded nose down with the RCS. Apparently, an error had been made during the servicing of the RCS system and instead of refueling with $H_2O_2$, nitrogen was used. The first command for nose down depleted the whole tank. Woodman had no way of getting the nose pointed back down. He later said he had pushed the stick all the way forward with no response. The airplane continued to fly almost straight up. Realizing he had no way of getting the airplane bent over the top, he attempted to sit back, relax and enjoy it. Knowing what we know now, his 70 degree climb angle made him a prime candidate for a pitchup.

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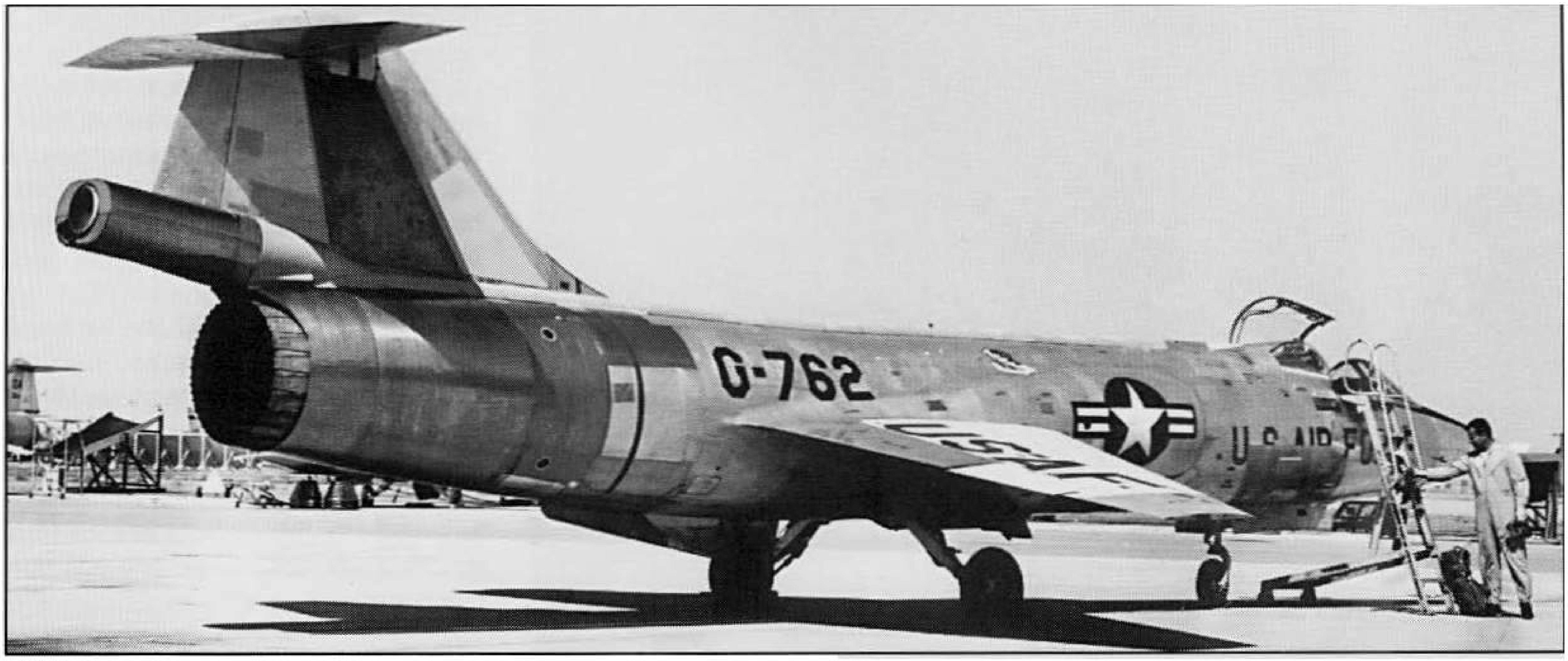
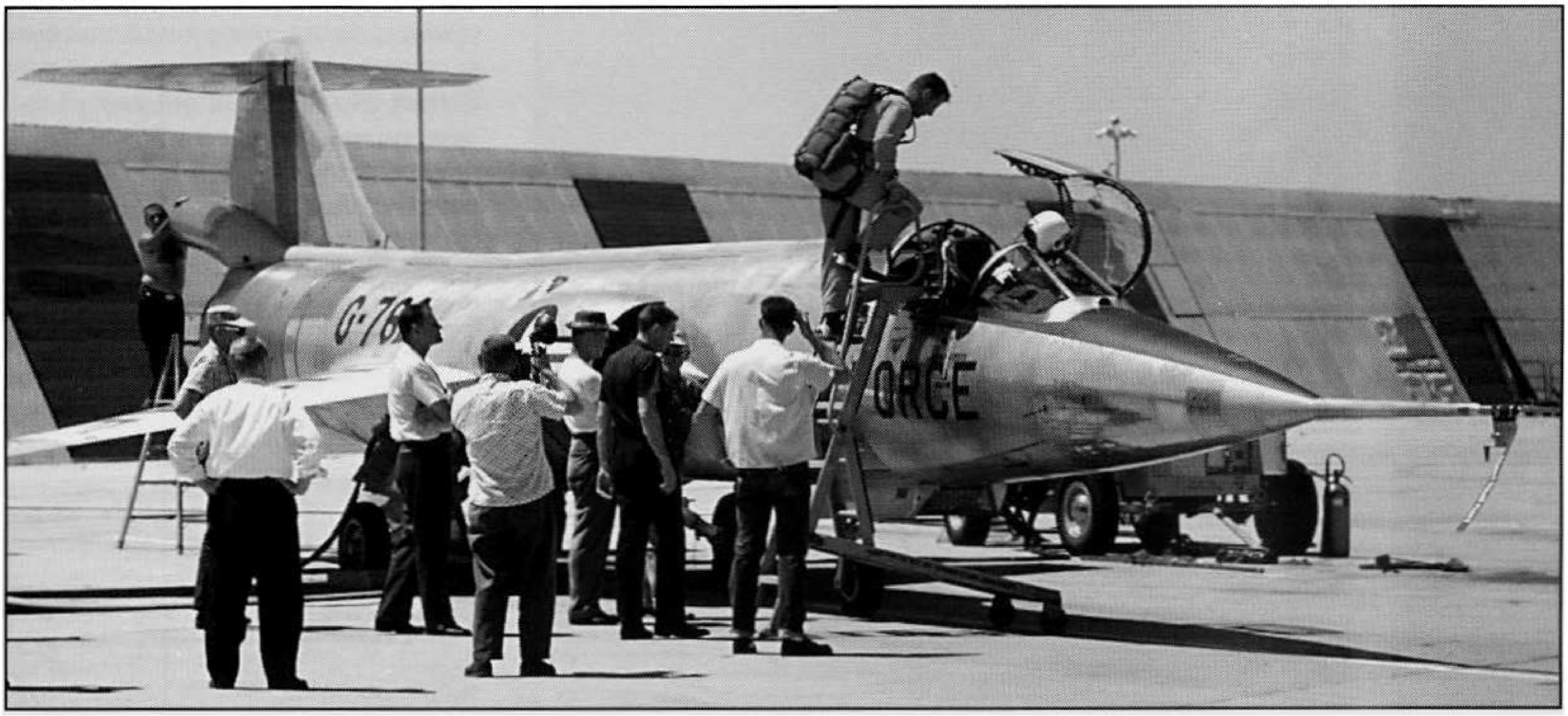
**Above left, Woodman preflights 762 prior to the first flight. (Lockheed via Tony Landis) At left, Jack Woodman poses by the exhaust of 762. (Lockheed via Tony Landis)**



It did, and he entered a spin. I was there in the radio room at the time. I heard Woodman say, "In a spin passing through 115,000". Every 5,000 feet he would report, "still spinning,110,000, 105,000, still spinning". Aircraft and occupant spiraled down out of control for the next 55,000 feet. At 60,000 feet, he was able to get and hold the nose down. At 35,000 feet, he said "I have a good light on the engine and everything is normal, I'm returning to base". He landed the airplane, taxied back, got out and that was another day's work. To my knowledge, this was probably the longest spin at high altitude to date, taking 80,000 feet to recover."

**Above, Woodman finishes up preflight of 762. (via Norm Taylor) At right, famed Aviatrix Jackie Cochran gets a close-up view of 762. (Lockheed via Tony Landis) Below, Jack Woodman climbs into the cockpit of 762 for its first flight after its conversion. Aircraft's spine and lower rocket fairing were primer yellow. (Lockheed via Tony Landis)**



## FLAT SPIN

Records were made to be broken and the Russians did just that when they wrestled away the altitude mark from the F-104. A Mikoyan-Gurevich built E-166 raised the bar to 113,890 feet.

On October 1, 1963, the Air Force Flight Test Center accepted delivery of the first NF-104. Plans were set into motion by Colonel Charles "Chuck" Yeager, Commandant of the Aerospace Research Pilots School, to win back the altitude record from the Russian MiG using the NF-104. Air Force Major Robert Smith, who had been assigned as the Project Pilot, began making preparation flights in the AST out of the Lockheed facility at Palmdale. Both Smith and Woodman bested the 113,890 mark on October 22 and 23, but these were practice flights only. The attempt came on November 15, when Smith zoomed to 118,860 feet setting a new unofficial record for an aircraft that takes off and lands under its own power. Smith later beat his own record on December 6, when he topped 120,800 feet.

With the aircraft now transferred to the Air Force Flight Test Center, Colonel Guy Townsend, the Test Wing Commander, ordered a test program under the cognizance of Air Force Flight Test Engineering and Test Operations. This was to be completed prior to turning the aircraft over to the Aerospace Research Pilots School. However, before any of that was to take place, an official altitude record attempt was to be made with the aircraft. The attempt would be made by the Air Force's most experienced rocket pilot, Colonel Chuck Yeager. Monitors from the Federation Aeronautic International would be on hand to record the attempt. On the

**Above left, Col. Yeager sits in the mock-up NF-104 cockpit and demonstrates the RCS control handle. (via Tony Landis) At left, Yeager conferring with Lockheed's legendary test pilot Herman "Fish" Salmon. (Lockheed via Tony Landis)**

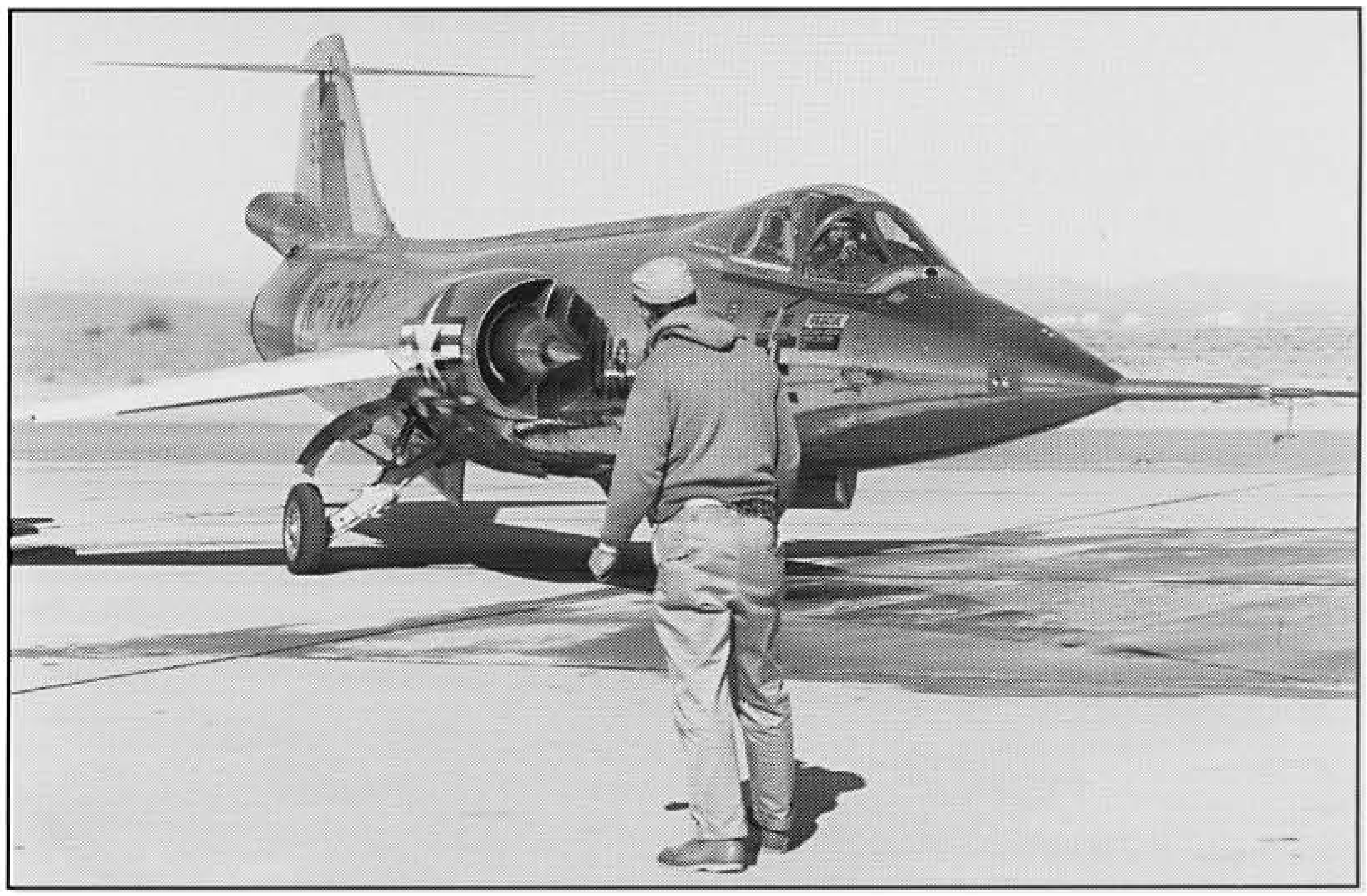
morning of December 10, Yeager made his first of two planned buildup flights for that day. Peaking out at 108,700 feet in tail #760, Yeager experimented with high angles of attack during the zoom, successfully controlling it with the reaction controls. Word had also come that day of the X-20's cancellation, setting the mood for another setback.

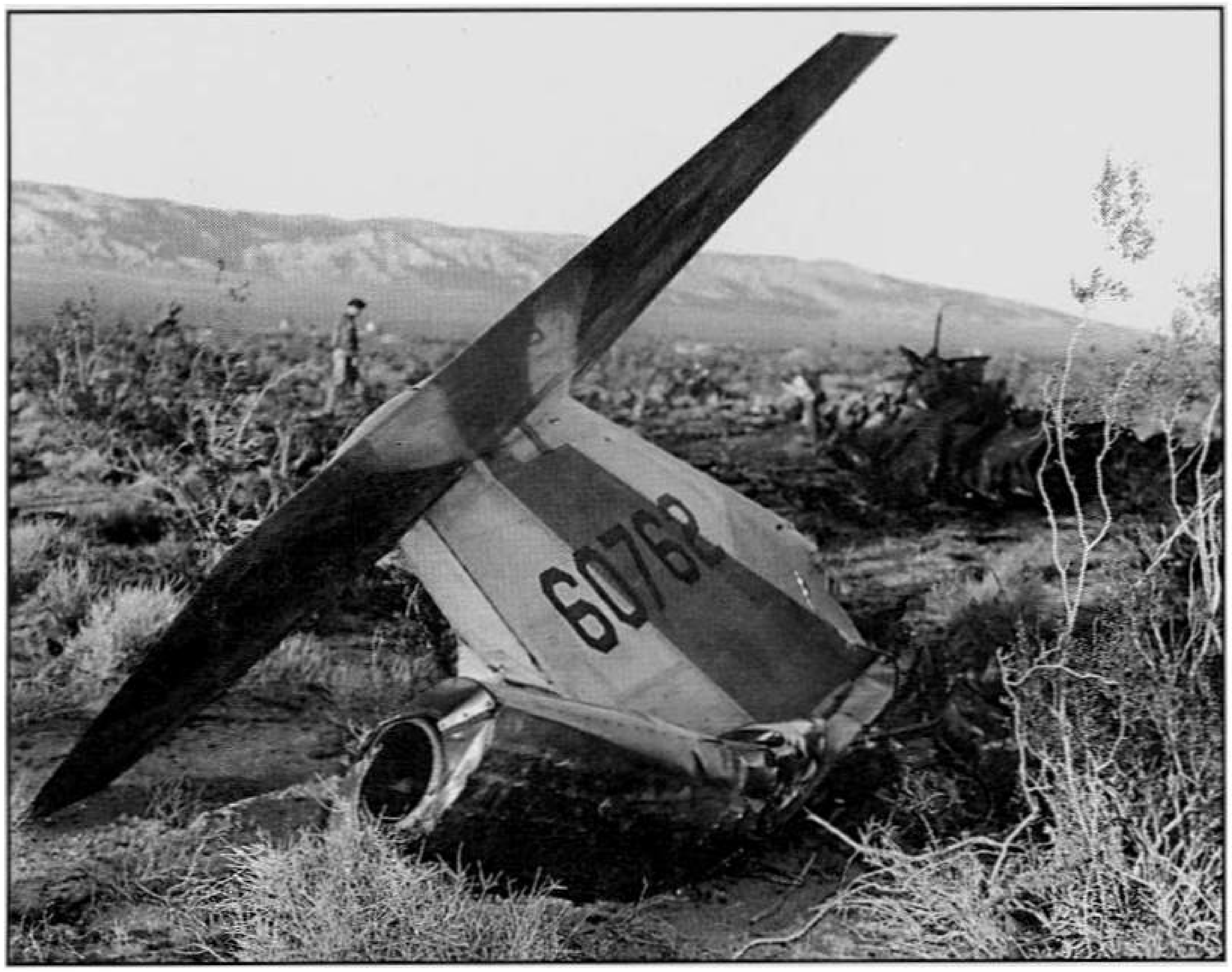
Yeager's flights that day were being further monitored by a ground based Nike radar station. This radar site monitored Yeager's zoom performance and supplied him with position and altitude information. On his second flight that afternoon at 80,000 feet, the site called-out "angle decreasing" and at 90,000 feet reported "45 degree angle". Yeager responded by increasing his climb angle and angle of attack to a value above 15 degrees, hoping to get back on profile. At 101,595 feet, Yeager was flying almost straight up and tried to lower the nose with the reaction controls as he had done on the flight earlier that morning. This time there was no response, as the aircraft departed into a highly oscillatory spin, tumbling over the top at 104,000 feet. Descending through 65,000 feet, the spin then snapped back and reversed direction, entering a stable flat spin.

This was the first flat spin ever encountered by an F-104. In a flat spin there is very little airflow entering the engine's inlet to motor (rotate) the engine. Without sufficient rotation, the engine wouldn't start and without a running engine the hydraulic pumps failed to turn to supply system pressure. So, now the flight controls were locked up as well. Yeager deployed the RAT and drag chute at 34,000 feet, which righted the airplane and dropped the nose. At 180 knots, going straight down, Yeager jettisoned the drag chute. Unfortunately, the engine RPM was still insufficient for an engine start and there was no hydraulic pressure. The elevator was still frozen with the trailing edge up, the position it had been trimmed to for the climb. When the drag chute departed, the elevator put the aircraft back into another flat spin. At 11,000 feet Yeager ejected, suffering severe

**Above, Yeager being strapped into 760. (Lockheed via Tony Landis) Below, Yeager waves on his way down the runway. (Lockheed via Tony Landis) Bottom, cockpit closed, ready to launch. (Lockheed via Tony Landis)**

S. AIR FORCE
RESCUE
EMERGENCY ENTRANCE CONTROL ON OTHER SIDE
CANOPY RELEASE





burns when the smoldering seat motor impacted his helmet, shattering his visor during the free-fall. Yeager eventually recovered from this close call, but aircraft #762 was no more.

Why did the NF-104 behave so differently from other F-104s in a spin? An analog computer simulation of the NF-104 had been developed by Flight Test Engineer Bob Hoey and his staff at the Flight Research Branch. The simulator was earmarked for the ARPS to familiarize students and assist in mission planning. Hoey and his staff were able to duplicate the flat spin with the simulator, documenting the unusual spin characteristics of the aircraft. Still a mystery though was why the aircraft reacted so differently from other F-104s. Somebody suggested engine gyroscopic effect. A standard F-104 maintained high engine RPM during a spin. The opposite was true in the NF-104's case, with RPM stalled at close to zero. Hoey and his men reprogrammed their simulator to include the gyroscopic effect and behold! A turning engine made a big difference in the spin characteristics, causing the aircraft to oscillate in a spin, rather than stabilize flat.

Much has been said about the X-15 to this point and the role it played in paving the way for manned space flight. Only one pilot holds the distinction of flying both the X-15 and NF-104, and he is retired Air Force Colonel William "Pete" Knight. Knight was among the first group of men slated to pilot the ill-fated X-20 Dynasoar. After program cancellation, Knight went on to the X-15 project and earned his Astronaut wings for piloting the X-15 to 280,000 feet. On October 3, 1967, Knight set a speed record in the X-15 that still stands, by reaching 4,520 MPH or Mach 6.70.

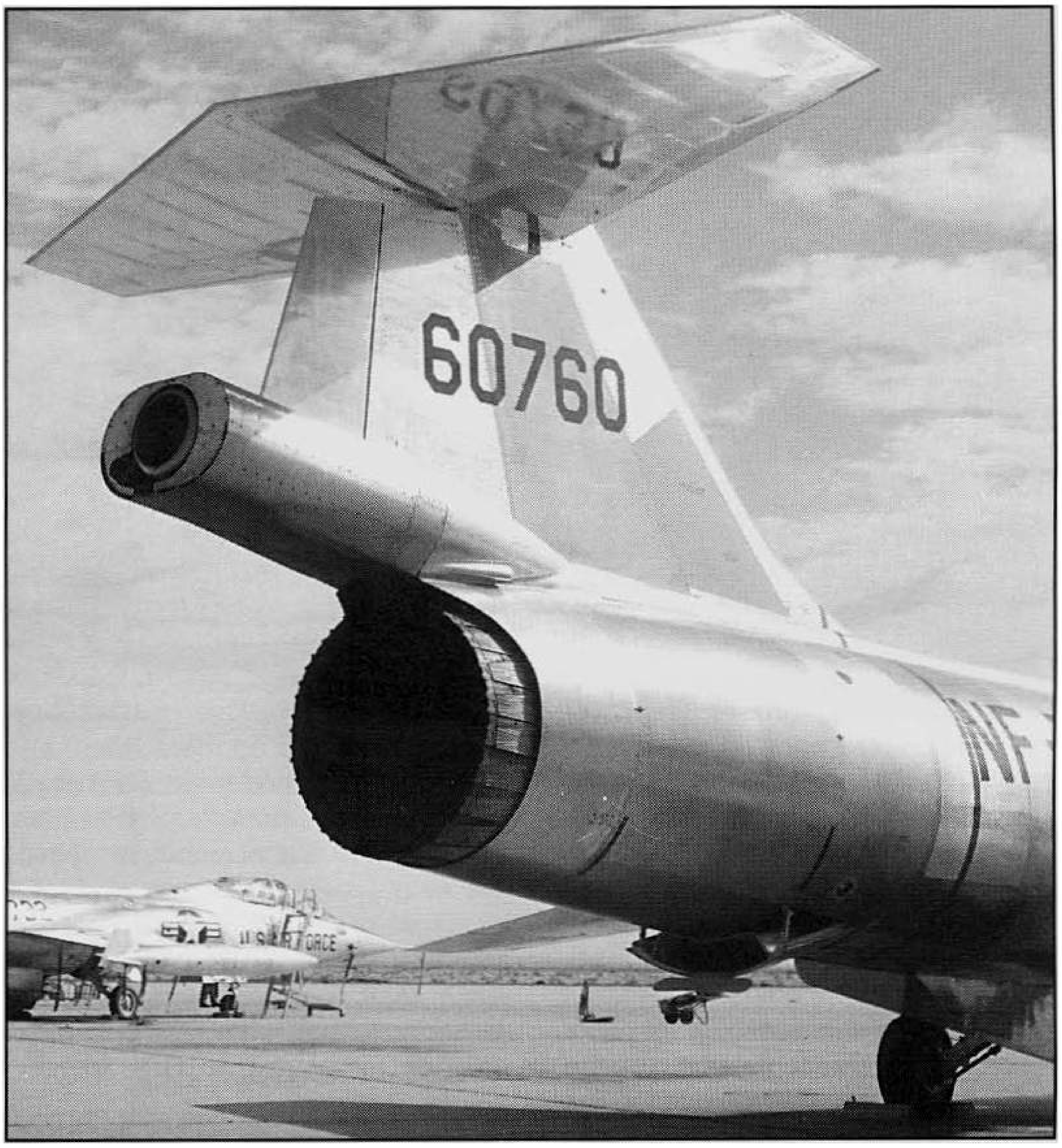
"My four flights in the NF-104

**Above left, all that remained of 762 after Yeager's accident was the tail. (via Terry White) At left, "Pete" Knight flew both the NF-104A and the X-15 to the edge of space. (AAFTC/HO via Scott Libis)**

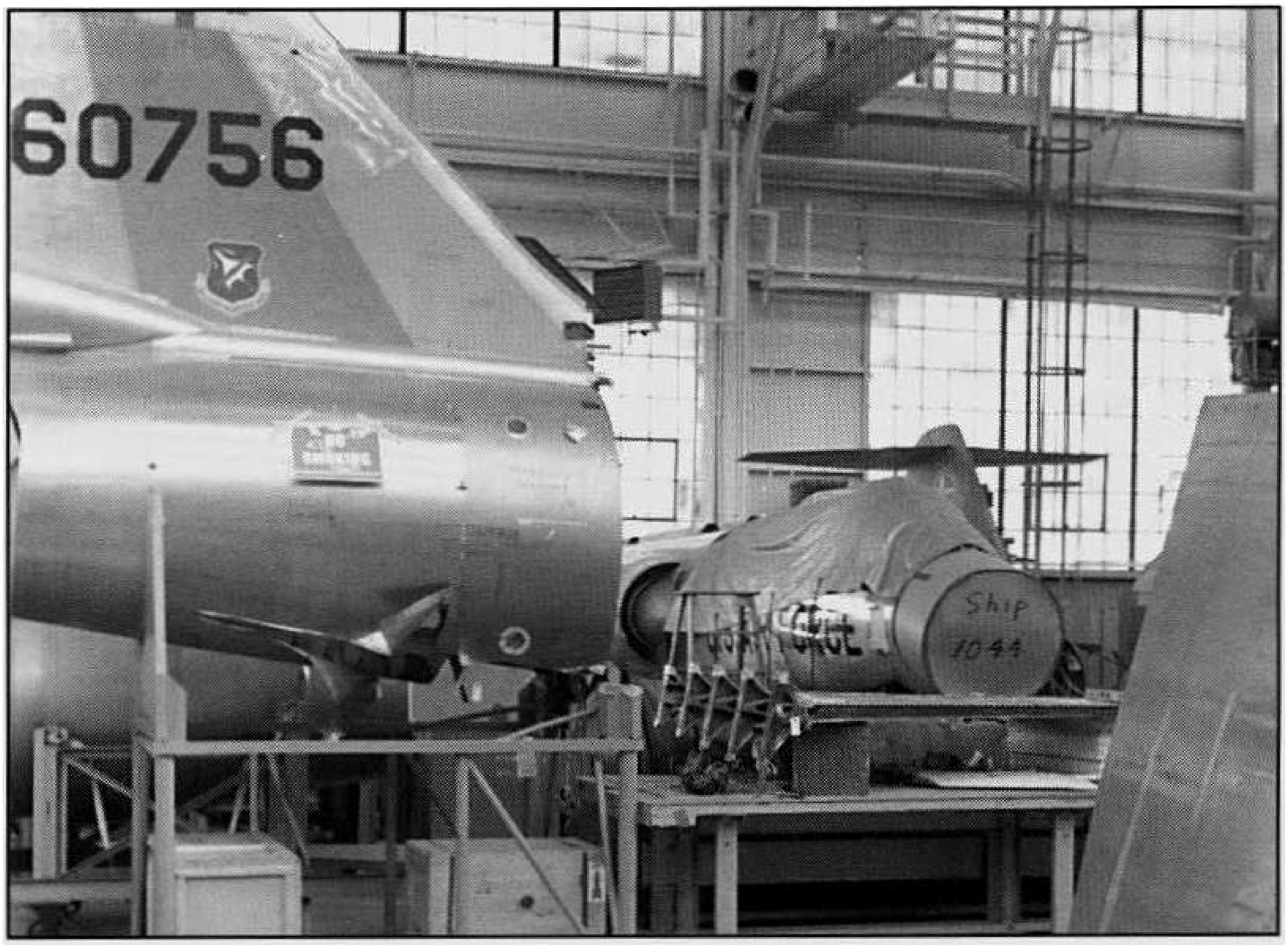
were in the wake of Chuck Yeager's accident with the airplane. At that time, I was a test pilot assigned to Test Operations at Edwards, and the NF-104s hadn't been turned over to the ARPs yet. We were to determine whether we could develop a profile that the ARPS could use safely. The profile was a little different from other programs. We would fly the airplane out to the Colorado River, turn around and head for Edwards accelerating normally with burner. Just before going supersonic, you used the rocket engine from .9 Mach to approximately 1.2, because that was a slow acceleration area for the '104. Then you would shut the rocket off and accelerate on out to Mach 2. At Mach 2, you started the climb and climb angles were probably in the neighborhood of 30 degrees. Once again, you would light the rocket, and on the way up you would close the afterburner somewhere around 75,000 feet, and the engine as well. This was to prevent an engine overtemp."

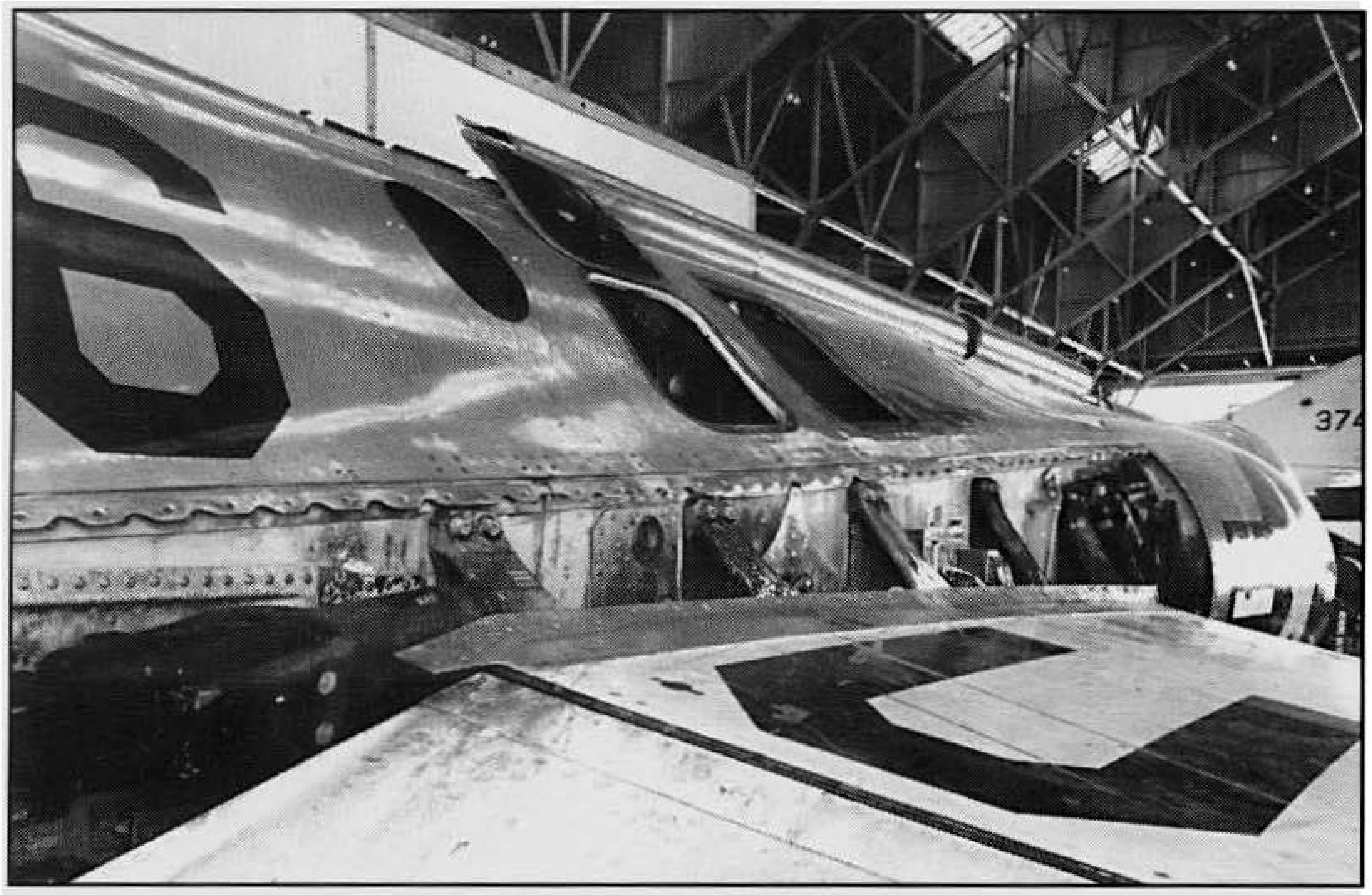
"In the boost phase, you were flying on instruments and busy working the check list, so most of your time was spent inside the cockpit. While in the later part of boost phase, during an X-15 mission, you would lose sight of the horizon outside of your cockpit window. That was not so on the profiles I flew with the NF-104. The horizon was always there, when there was time to look. At this point, you ran the rocket down to a fuel level of about three or four hundred pounds of total fuel and then shut the rocket off. The rocket keeps your speed up thoughout the climb. With a 30 degree climb angle, you would peak out at about 90,000 feet."

"At 90,000 feet, you had very little control with the aerodynamic control surfaces. As you went over the top, you would then transition to the reaction controls. The objective now was to maintain a set of conditions: angle of attack, roll angle and yaw angle using the reaction control jets. This set you up for the re-entry phase. Supersonic speed needed to be maintained to prevent pitch up and keep the "q" from dropping below a desired limit. On my flights, getting



**Above, drag chute door is open on the belly of 756. Note the 2-seat TF-104G chase plane in the background. (Lockheed via Tony Landis) Below, the skin has been peeled away from the aft fuselage by the explosion of the leaked hydrogen peroxide that had pooled in the lower fuselage. (Lockheed via Tony Landis)**



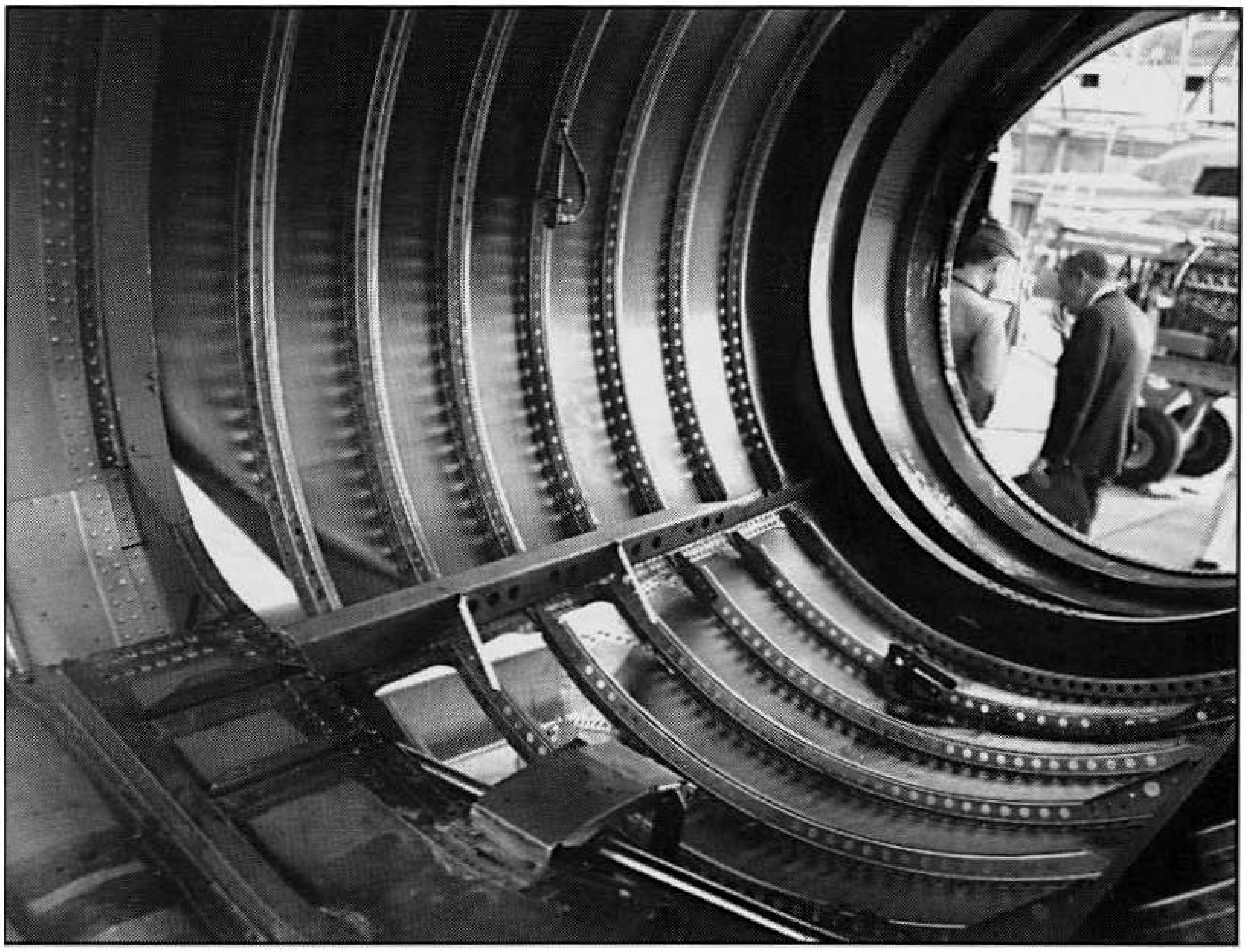


the nose pointed back down wasn't a problem as it tended to want to do that anyway. One of the many features borrowed from the X-15 was the RCS controller. This was the control handle we used like our flight control stick to activate the tiny RCS rockets in the nose and wing tips. The control laws were the same, except for pitch, which was reverse to the setup on the X-15. To get nose up, you pushed the control handle up, rather than down and vice versa for nose down. Roll and yaw remained the same."

"Our final recommendations to prevent Yeager's accident from happening again called for maintaining a minimum Mach number of 1.0 at the apex (peak) of the maneuver. Next, we established a minimum dynamic pressure of 20 psf at the apex and, finally, 50 degrees was to be the maximum climb angle to avoid any possibility of pitchup."

In addition to the procedural changes mentioned by Knight, hardware changes were also made. Minimum fuel flow and drag chute modifications were to be incorporated into the two surviving ASTs. The minimum fuel flow mod consisted of replacing the fuel flow controller with a modified controller that reduced the minimum fuel flow to the J79 engine. Instead of consuming 525 pounds of fuel per hour, the minimum fuel schedule was reduced to 325 pounds per hour. 325 pounds per hour compared to the 525 pounds per hour meant that the engine would be using less fuel, and this in turn meant that the engine would be running cooler. A cooler engine will take longer to heat up, and enabled the AST to fly higher with the engine operating. With this mod, the engine would still eventually reach its temperature limit in the zoom and have to be shut down. The major benefit derived from this would be higher engine RPM over the top, increasing the engine's gyroscopic effect, reducing the likelihood of a spin going flat.

Shortly after Yeager's flat spin, another pilot at Edwards, using a standard F-104, experienced a fully developed flat spin. He too was zooming a '104 when it went awry. Per the spin procedure, he also deployed his drag chute, but to no avail. In the swirling air of the flat spin, there wasn't enough energy in the spring-loaded chute to ensure clearance from the spinning aircraft. The chute became entangled with the spinning aircraft and never opened. The pilot ejected to safety as the aircraft spun-in to destruction. A different recovery system was developed as a result of this accident and modified onto the AST's. This new system entailed a drogue-actuated chute arrangement, where a drogue fired projectile would be tethered to the drag chute, ensuring positive separation from the aircraft. Furthermore, the length of the chute's risers was increased to ensure adequate separation. Validation of this modification would come from ground tests, rather than risking a pilot and aircraft in actual flight tests.



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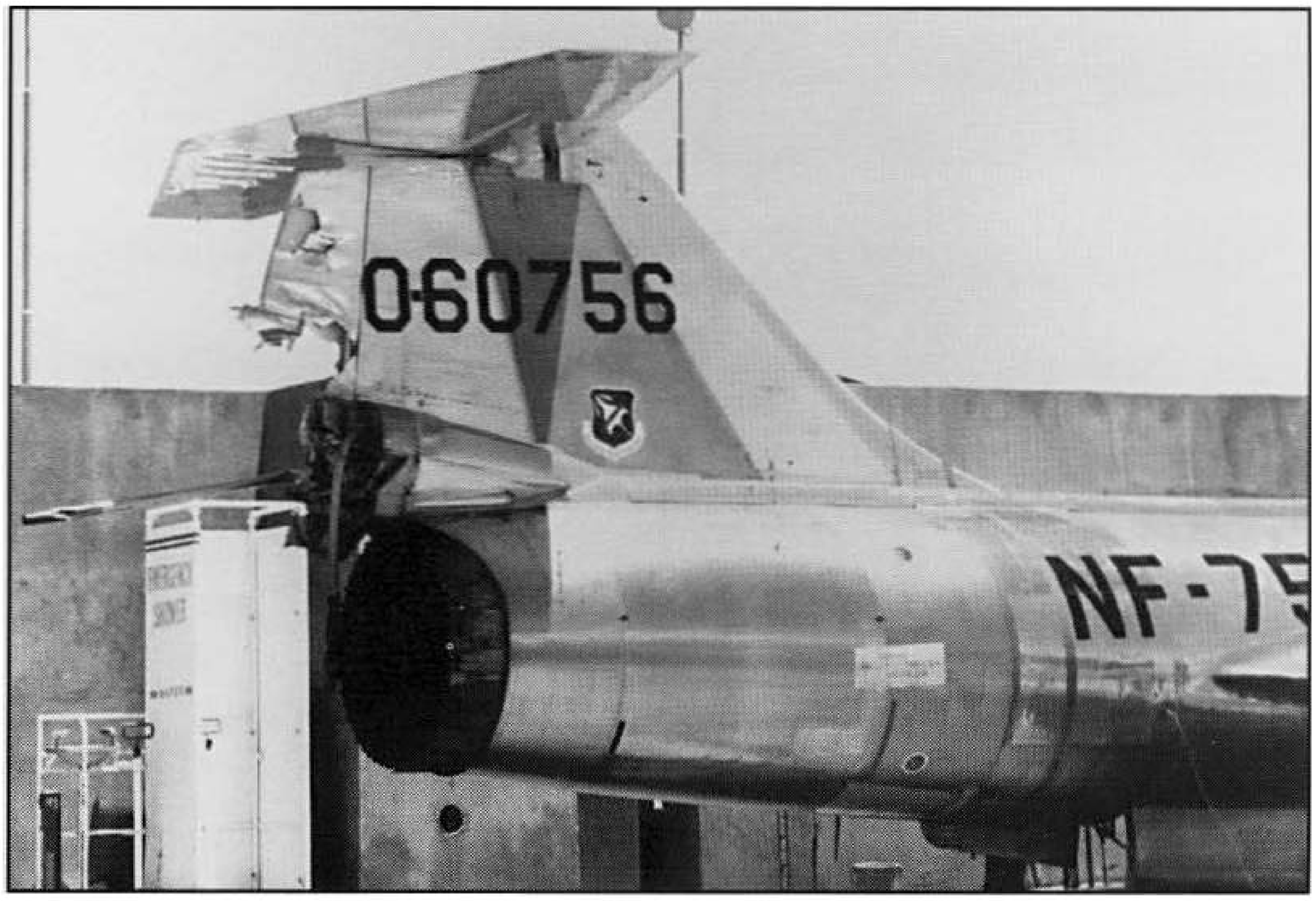
**Above left, wing root damage to 756 after the in-flight explosion. At left, note how the skin was peeled from the circular fuselage ribs by the explosion. (Lockheed via Tony Landis)**

## HYDROGEN PEROXIDE INCIDENTS

All of 1964, through June of 1965, must have been an overwhelming experience for the Air Force's NF-104 test team. Category II flight testing dictated a very ambitious flight schedule, this in addition to working in time to incorporate the minimum fuel flow and drag chute modifications. The fuel flow mod proceeded without a hitch, but the chute mod was experiencing unforeseen difficulties and took some time to complete. 68 flights would be flown during this time.

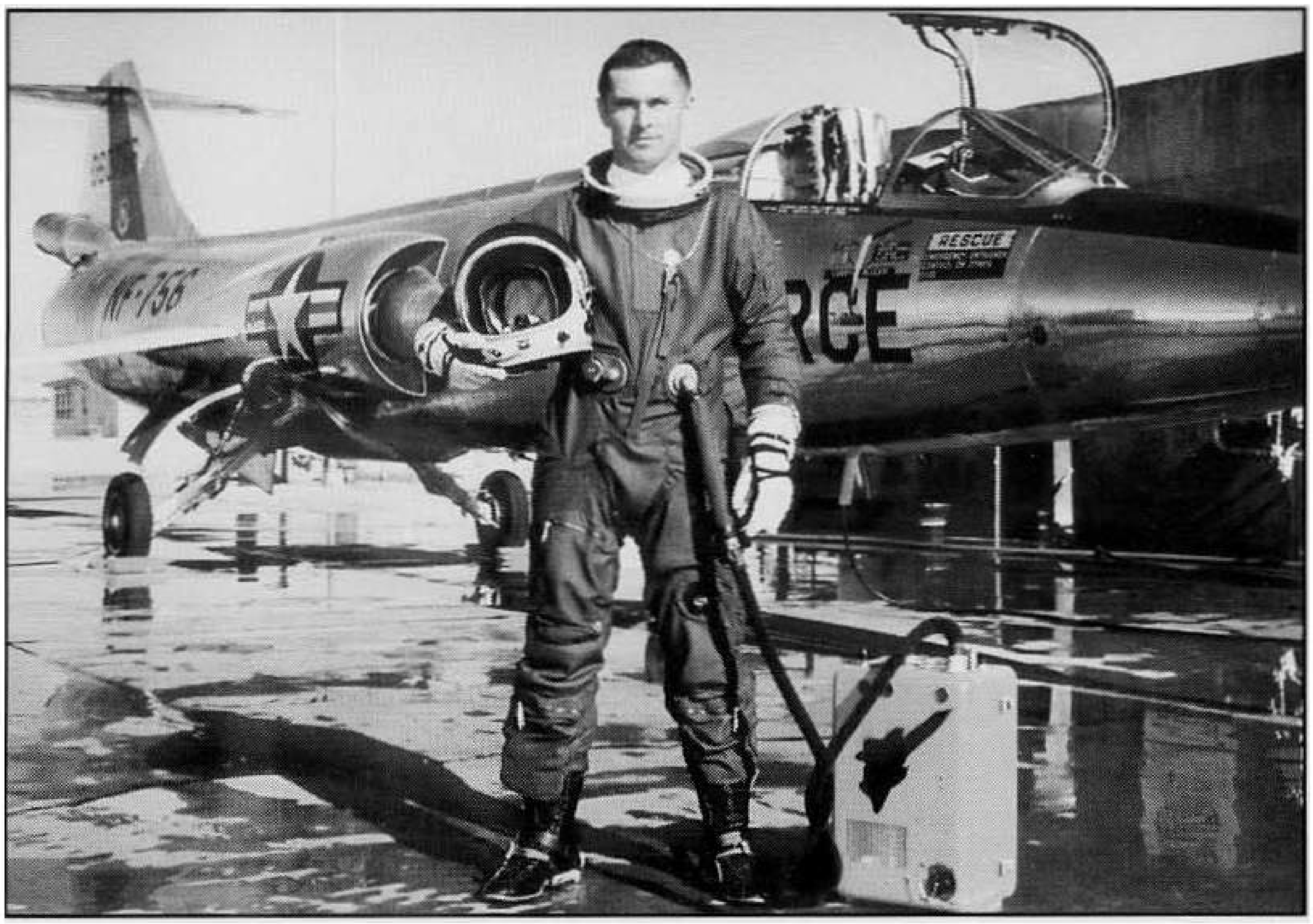
Starting on July 5, 1964, the first in a series of disturbing $H_2O_2$ mishaps occurred. Left unattended over the July 4th holiday, the main $H_2O_2$ tank bellows ruptured on #760. Contamination was ruled the cause when the tank was inspected and signs of oxidation discovered. $H_2O_2$ is highly corrosive and only compatible with a few materials. The grade of stainless steel used in the tank sumps had a high content of iron, and this led to the oxidation, which led to the reaction causing the tank to overpressurize and rupture. A different grade of steel would be selected, one more compatible with $H_2O_2$. Eventually, a new set of tanks would be fabricated and retrofitted onto both aircraft. This incident also drew attention to another design flaw. After a typical mission, several gallons of $H_2O_2$ would be left over, trapped with no feasible way of scavenging the remaining propellant from the sumps. The aircraft would then sit parked for days, or possibly, weeks with this highly caustic liquid on board. A gaseous nitrogen purge system would be devised and installed on both aircraft, allowing for the complete purging of all $H_2O_2$ by the pilot during the landing phase of the mission. The plumbing of this system facilitated the dumping of the remaining $H_2O_2$ out of ports on the left and right wing tips and the dump mast running along the left side of the rocket engine fairing. Completion of this modification would take some time.


Above, when the rocket motor blew off with much of the rudder, it marked the end of the program. (via Craig Kaston)

Next to fail was the left and right wing RCS slip joint fittings located at both wing roots. These fittings would separate under certain wing loads in flight, exposing an o-ring seal, momentarily allowing some $H_2O_2$ to leak into the wing. Nothing happened on the first two flights this was noted on. However, on the third occurrence, enough $H_2O_2$ leaked out to accumulate in the right wing and migrate down to the lower parts of the fuselage. The resulting chemical reaction caused an explosion, damaging the lower fuselage and wing root. This explosion went unnoticed by the pilot, who returned to base and landed without incident. By this time, the Flight Test Engineers were more than just a little concerned about the $H_2O_2$ leaks and contamination situation on both ASTs. The decision was made to ground both ASTs so that both the sump oxidation and leak issues could be addressed. ARPS would have to wait for their trainers.

It wasn't until May 6, 1967, before both aircraft were ready to resume flight test activities. The slip fitting issue was laid to rest by replacing the fittings with positive lock connectors, installed on flex lines. Another six flights were made when an inspection revealed that the new sumps were also prone to oxidation. The aircraft were re-grounded, while the search went on for an answer to the tank oxidation problem. Next up, engineering ordered the tanks to be passivated, or super-cleaned. Passivation, coupled with the new nitrogen purge system, was deemed to be a suitable fix by engineering, and the aircraft were returned to service in February of 1968. By May, one Project Pilot and Two Instructor Pilots had received check flights in the ASTs. ARPS was finally cleared to begin student training. Air Force Flight Test Center Commander, Brigadier General Alton Slay, zoomed to 85,000 feet using a 35 degree climb angle on April 9, 1969. By October 1, 1969, AST students had racked up 29.9 hours of flight time, compared to 39.1 for the instructor pilots.

Training flights with the AST continued on incident-free until June 15, 1971. On this date, student pilot, Captain Howard "Whitey" Thompson, was flying #756 accelerating for a zoom. "Whitey" attempted to light the rocket engine to help him through the transonic portion of the profile, when he felt and heard a loud explosion. He immediately shut the rocket engine off, then felt another explosion. His chase aircraft reported that his rocket and part of his rudder had disappeared. An emergency was



**At left, Capt. Warren Kerzon prepares to board in full pressure suit. Note steel cable attached to the press suit's neck ring. While seated with a fully pressurized suit, the neck ring and helmet would tend to rise, obscuring the pilot's vision. This would be prevented by cinching down the cable prior to suit inflation. (AFFTC/HO via Scott Libis)**

declared and "Whitey" landed without further incident on Rogers Dry Lakebed. The culprit, once again, was a leaking $H_2O_2$ fitting allowing the $H_2O_2$ to migrate to the rocket engine. Training with the ASTs was terminated in December of that year, but not before Major Dean Vikan set a student altitude record of 113,087 feet using a 40 degree climb angle.

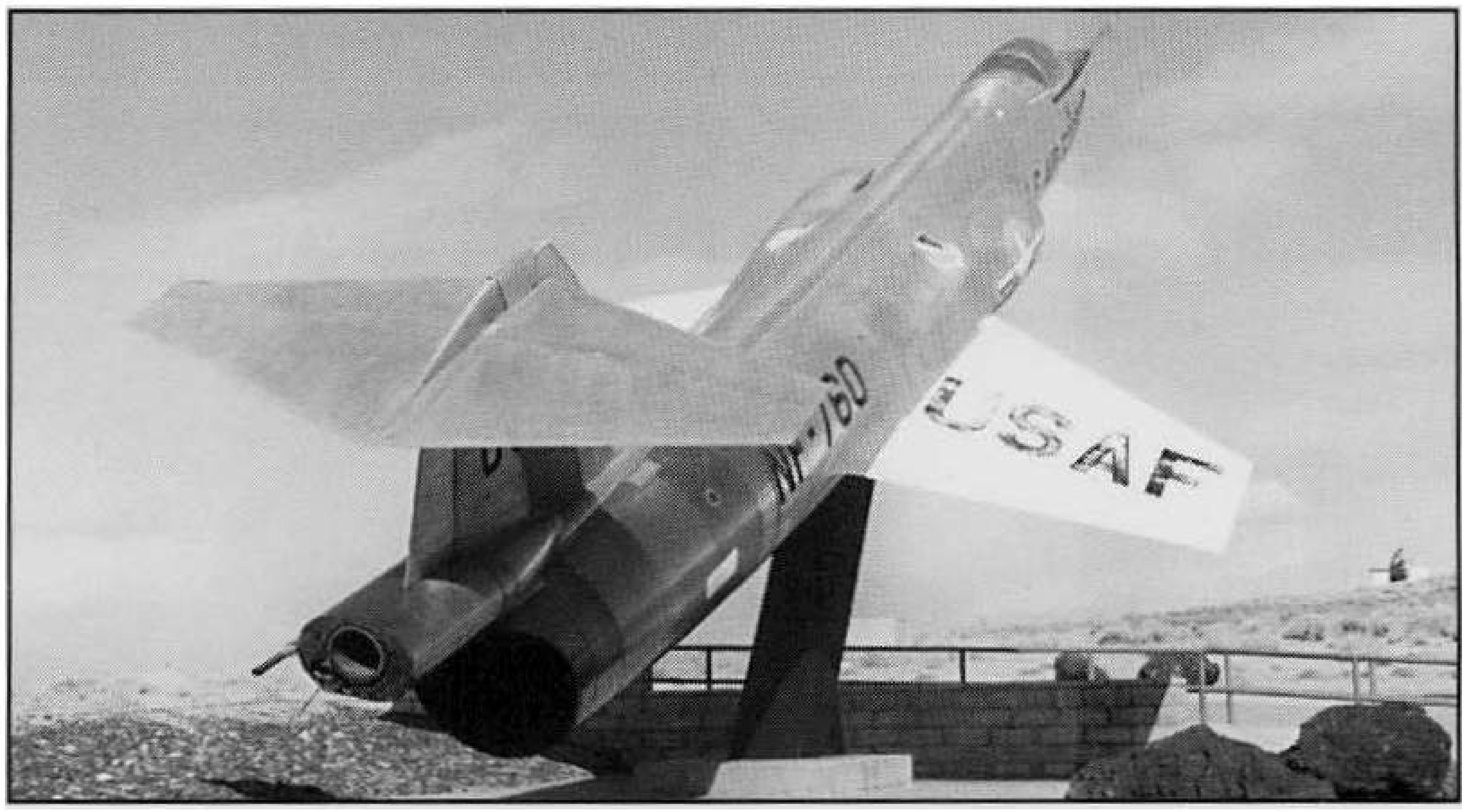
Soon after #756's grounding, NASA was given permission to use the still serviceable wing extensions. The time required to remove the wing extensions from #756 and install on one of NASA's F-104s was minimal. NASA then undertook a brief flight test effort to evaluate the benefits of the wing extensions for chase missions. No difficulties were experienced during the abbreviated test program, and the final disposition of the wing extensions is unknown. It is possible that any advantage the wingtips offered was marginal, and the concept was scrapped.

## OLD AGE

When pushing technology, sometimes initial estimates fall short of actual performance. In the case of the AST, this happened to some degree, however technology still advanced. As might be expected, the Aerospace Trainer aged quite quickly due to the series of mishaps that plagued the program. Deactivation of the RCS kicker and rocket throttle became

**At left middle, Capt Joe Jordan in pressure suit, helmet and mask. (via Tony Landis) At left, five NF-104A pilots. Top row left to right: Jim Rhodes and Fred Dante. Bottom row left to right: Hardy Shogan, Chuck Stone and Jim Rider. (via Scott Libis)**

**Above, NF-104 pilot James Rider.**



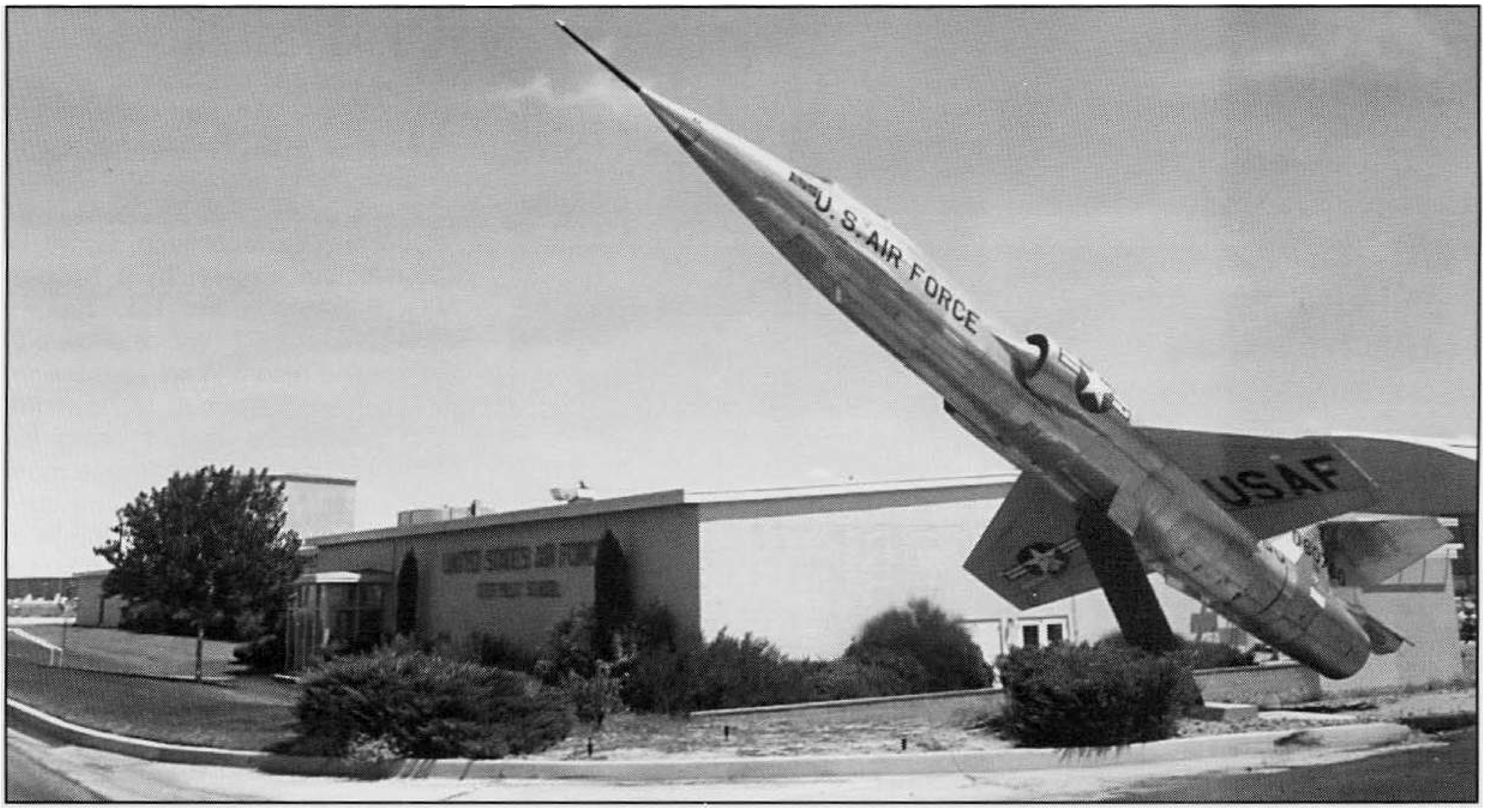
**Above, the surviving NF-104 on its pylon in 1999. The extended wing tips and the RCS nose were removed. (Scott Libis)**

necessary due to unpredictable performance. Rocket engine turbopump maintainability was also troublesome, with problems ranging from bearing failures to oxidizer and fuel seal leaks.

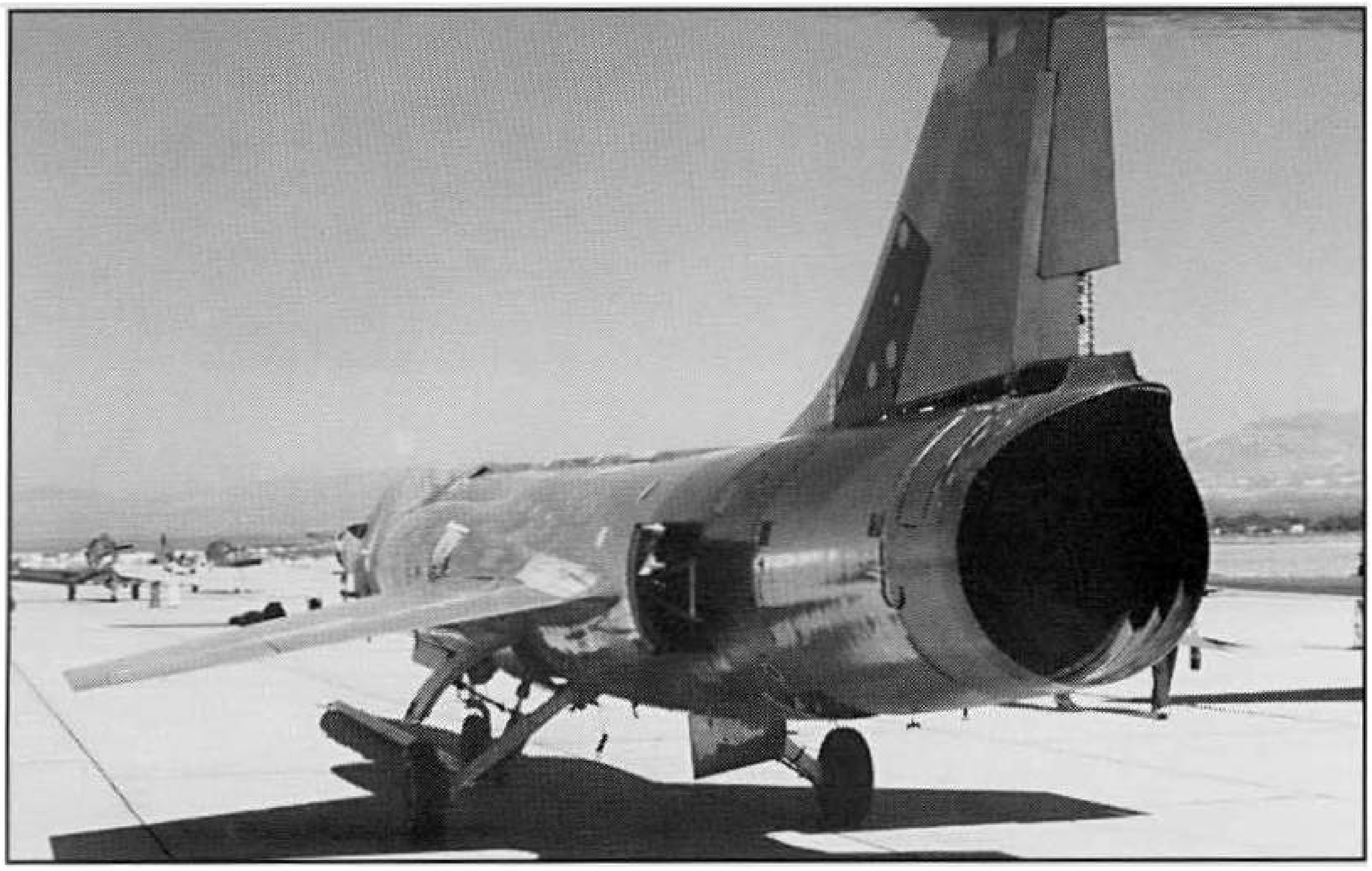
On June 1, 1972, the Aerospace Research Pilots School was re-designated once again, to United States Air Force Test Pilots School. This change reflected the change in curriculum from the aerospace course to a new systems oriented curriculum. With the elimination of the X-20 in 1963, and the Manned Orbiting Laboratory (MOL) in 1967, the Air Force no longer had a reason or mission to train space pilots. Another reason for the change is the dynamic nature of technological advancements. The school's curriculum must remain in a continuous state of evolution to guarantee that the most current subject matter and teaching methods are used.

The Aerospace Trainer became the school's centerpiece, and both the school and aircraft contributed much to the advanced studies in manned space exploration. In the end, approximately 50 pilots flew the NF-104s on 302 flights, accumulating 8.6 hours of rocket engine operation. 65 graduates from the school would later be selected to become astronauts.

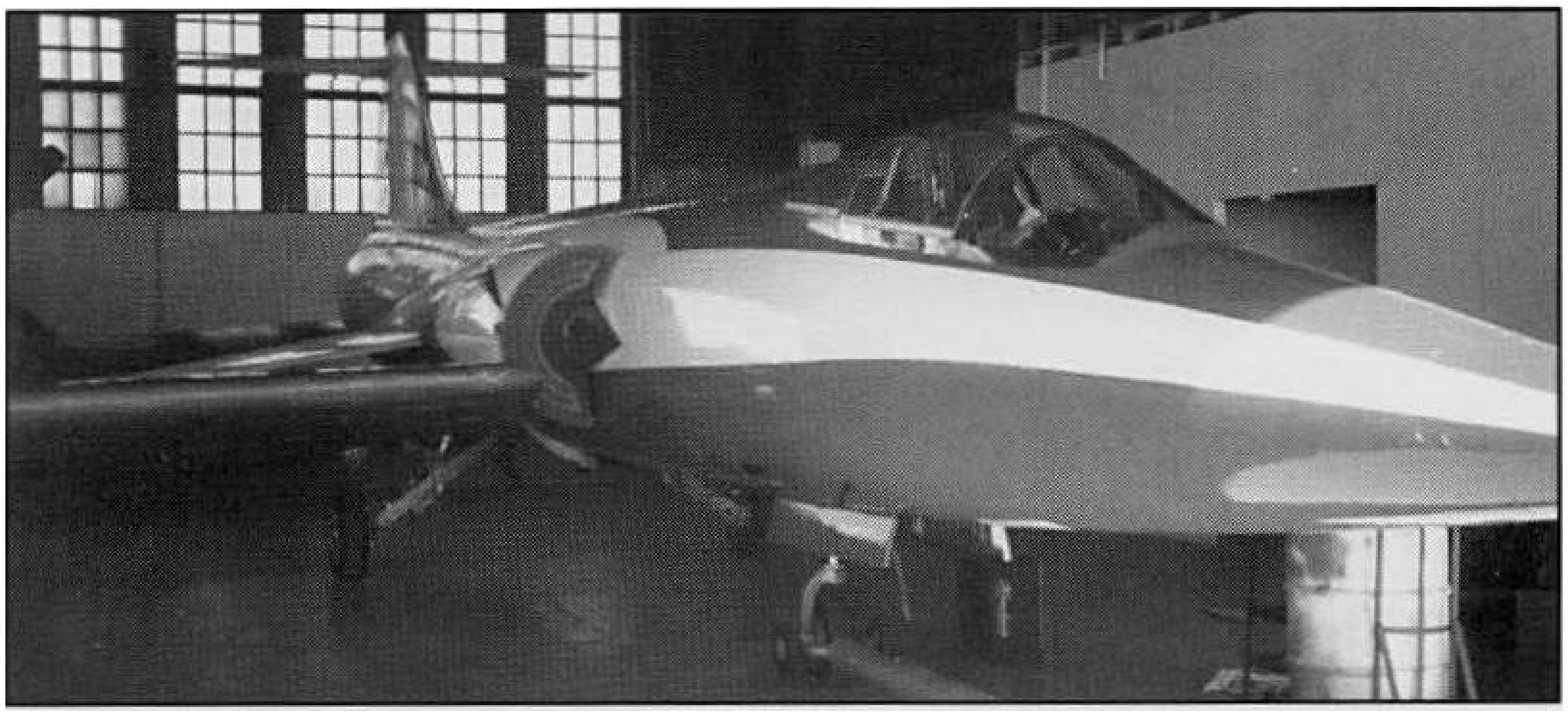
**Below, the NF-104 in front of the United States Air Force Test Pilot School at an earlier time before the removal of the RCS nose for use in the Red Baron's attempt at a world altitude record. (AFFTC/HO via Scott Libis)**

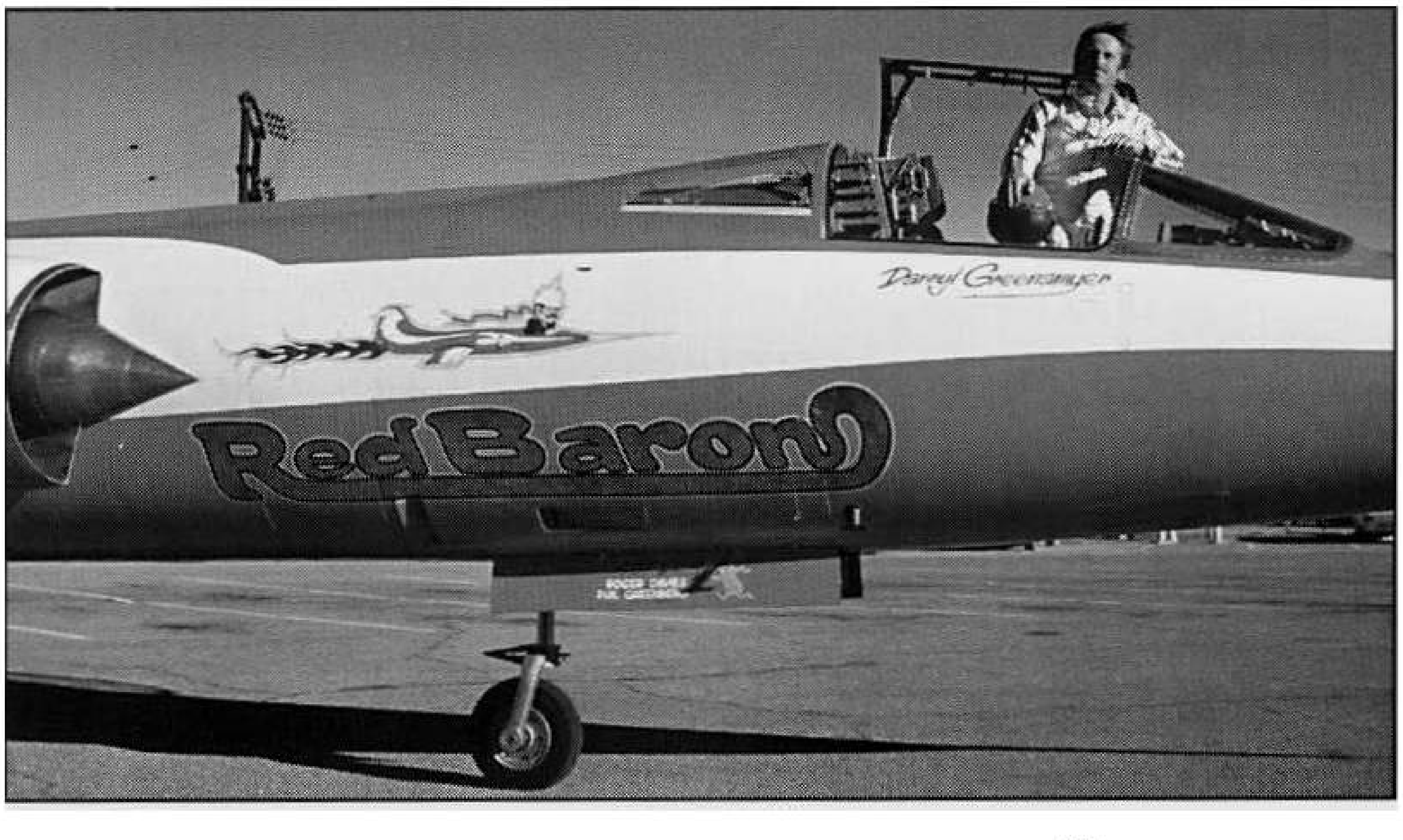


# DARRYL GREENAMYER'S RECORD SETTING RED BARON



**Above, on the ramp at Mojave, Greenamyer's Red Baron starts to look like a real airplane in 1975. (Steve Ginter) Below, the Red Baron sits in its hanger in early 1976 after being painted red and white. The extended RCS nose that was loaned from Edwards is fitted. The covered RCS ports can be seen on the side and top of the nose cone. (Steve Ginter) Bottom, publicity photo of Darryl in the cockpit of the Red Baron after the graphics had been added. Red Baron was inlaid gold outlined in yellow. (via Tony Landis)**





## POST SCRIPT

In 1976, long after the grounding of the two surviving NF-104s, another RCS configured F-104 would take to flight. Privately sponsored, this venture was spearheaded by former Lockheed test pilot Darryl Greenamyer. Greenamyer had spent 13 years piecing together an airworthy F-104 from military surplus scrap heaps and civilian junk yards. The end result was a highly modified F-104 that, in 1977, won the low altitude speed record by attaining 988.088 mph, 60 feet above a dry lake bed in Nevada.

Dubbed the *"Red Baron"*, the airplane was the product of volunteer workers unencumbered by the stifling myriad of military specifications. Close adherence to mil-spec is mandatory when manufacturing, modifying, or maintaining aircraft in service with the U.S. Government. An ingenious water injection system was devised for the engine, increasing the mass flow through its core. Not only did this provide for lower operating temperatures, it increased the engine's operating redline from Mach 2.3 to 2.6. Being privately owned, Greenamyer was responsible only to himself. Freedom from the Air Force's rigid flight and engine operation limitations empowered Greenamyer to take the *Red Baron* to the edge of total destruction, squeezing out every bit of performance.

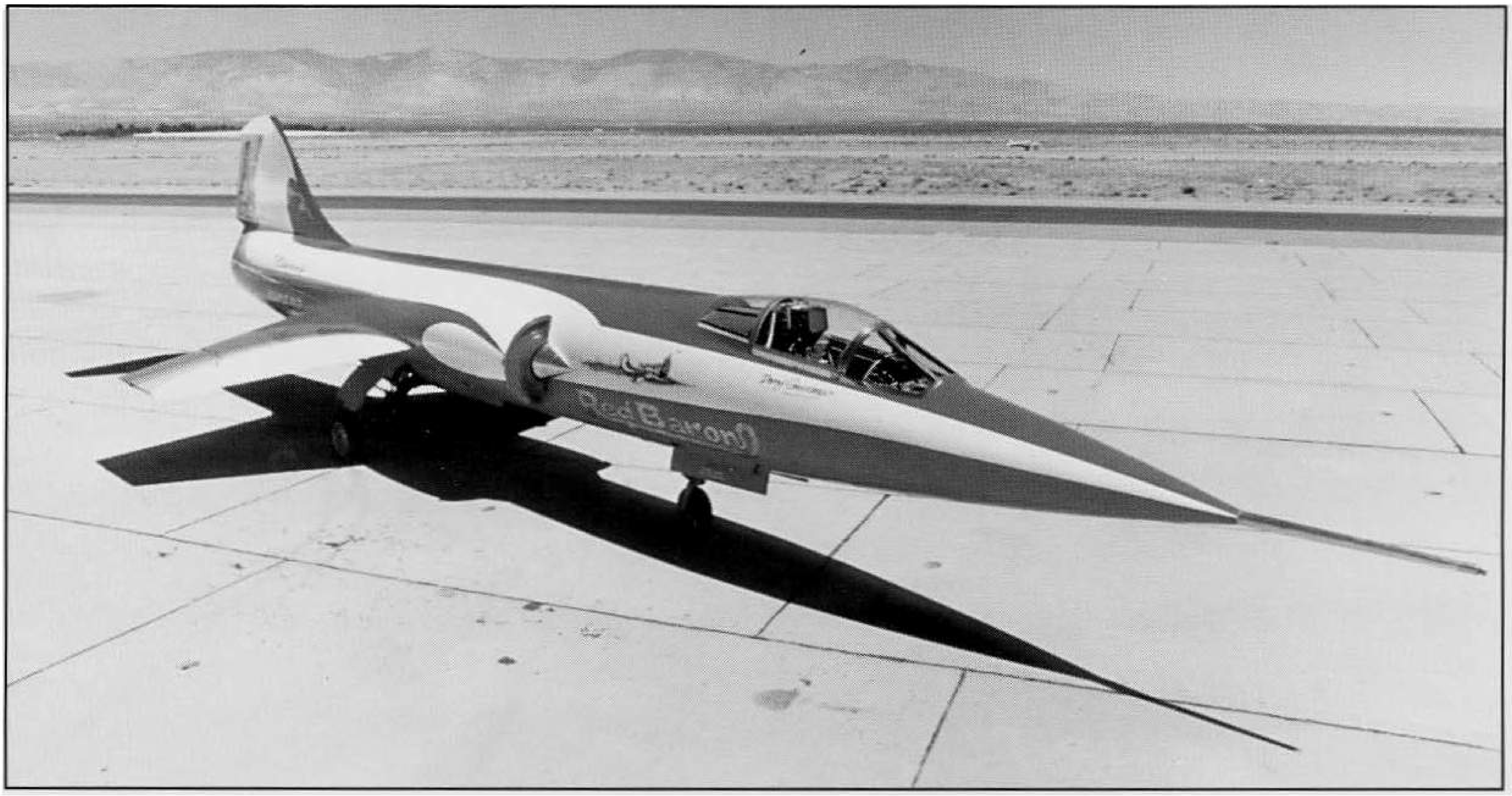
A new world altitude record of 123,000 feet was set by a Russian MiG-25 following the *Red Baron's* speed run in 1977. With the low altitude speed record in his possession, Greenamyer set out to top the Russian altitude record using his hybrid F-104. His F-104 was a more than capable competitor, as he proceeded to borrow structure and RCS components from the Air Forces Test Pilot School's NF-104 static display. On loan from the school to Greenamyer were tail #760's two-foot wing extensions, metal nose cone and reaction control components. A climb angle in excess of 50 degrees was part of the flight plan, and the stabilizing effects of #760's reaction control system would be a welcome addition. This would help even the score when going up against the latest advance in Soviet fighter technology. In order to be successful, the *Red Baron* would have to beat the MiG-25's record by 3 percent, or roughly 4,000 feet, to be recognized as a world record.

A series of practice flights were flown out of the Mojave airport in Southern California in preparation for the attempt. The team of volunteers ironed out the last of the bugs, and then on February 27, 1978, a full-up practice zoom flight was made. Everything went smoothly, until the end of the flight when Greenamyer tried to lower the landing gear. The right main landing gear did not indicate down and locked on the landing gear control panel in the cockpit. Rules governing this condition in an F-104 stipulated that the pilot must confirm the gear down and locked, or abandon the aircraft. Landing the '104 with one main gear, or belly landing, was considered to be unsurvivable. The gear could be verified as down and locked by either a ground observer, or chase aircraft.

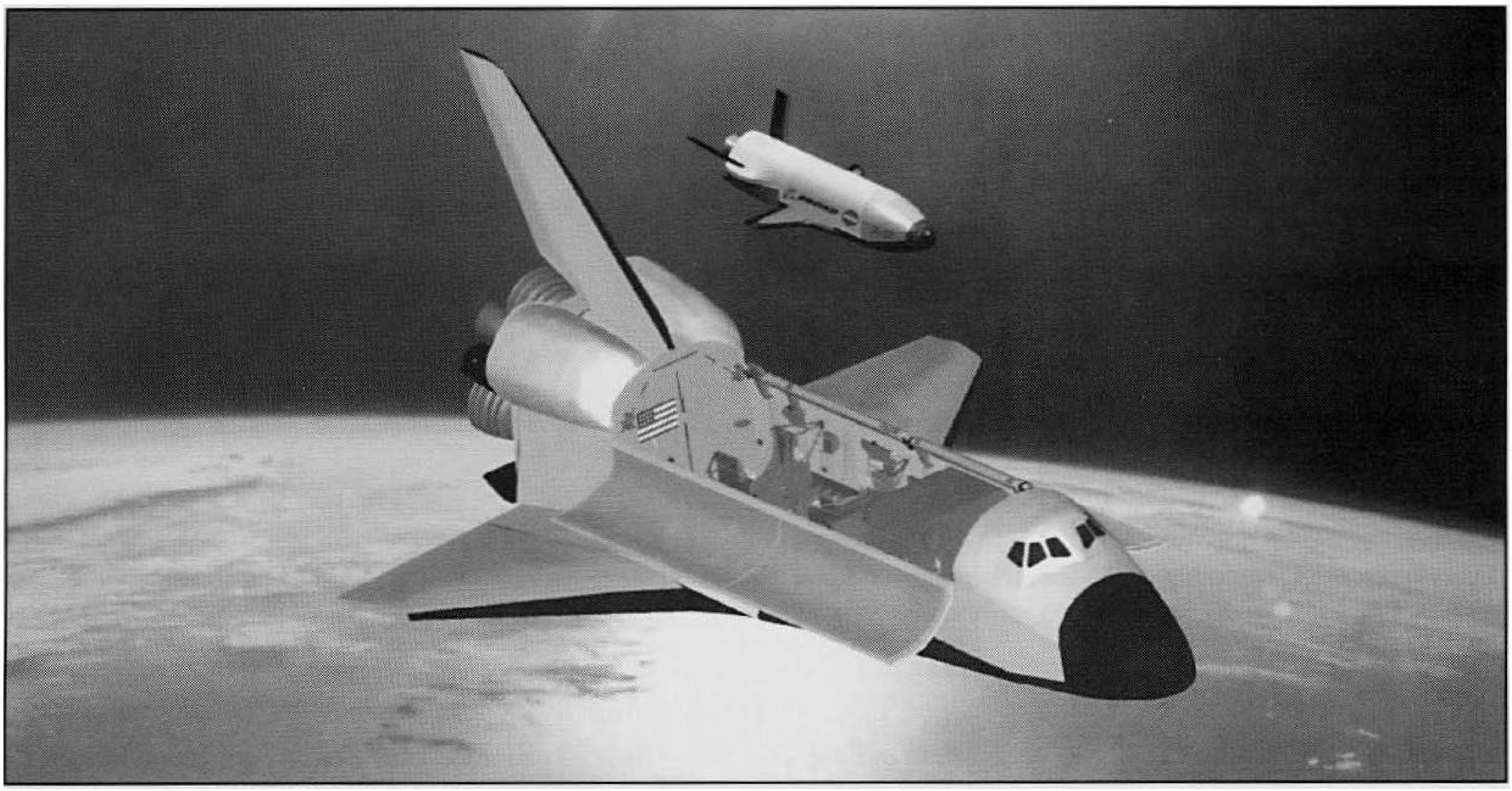
Struggling to stay airborne at 200 mph Greenamyer made low and slow passes hoping for visual conformation. Even at 200 mph, visuals proved impossible from the tower and ground observers positioned at the Mojave airport. Low on fuel, Greenamyer took the stricken *Red Baron* 30 miles to the south, to Edwards AFB, where he hoped a chase plane could be scrambled in time to give him his visual. His fuel state further decayed upon entering Edwards airspace, to the point where he could no longer wait for a chase plane. Faced with only one option, Greenamyer took his crippled aircraft out to an abandoned bombing range on the base and ejected.

13 years of hard work ended that afternoon, but not before winning the low altitude speed record. Whether or not Darryl Greenamyer and his *Red Baron* could have beaten the altitude mark remains a point of debate, although many believe he certainly had a chance.

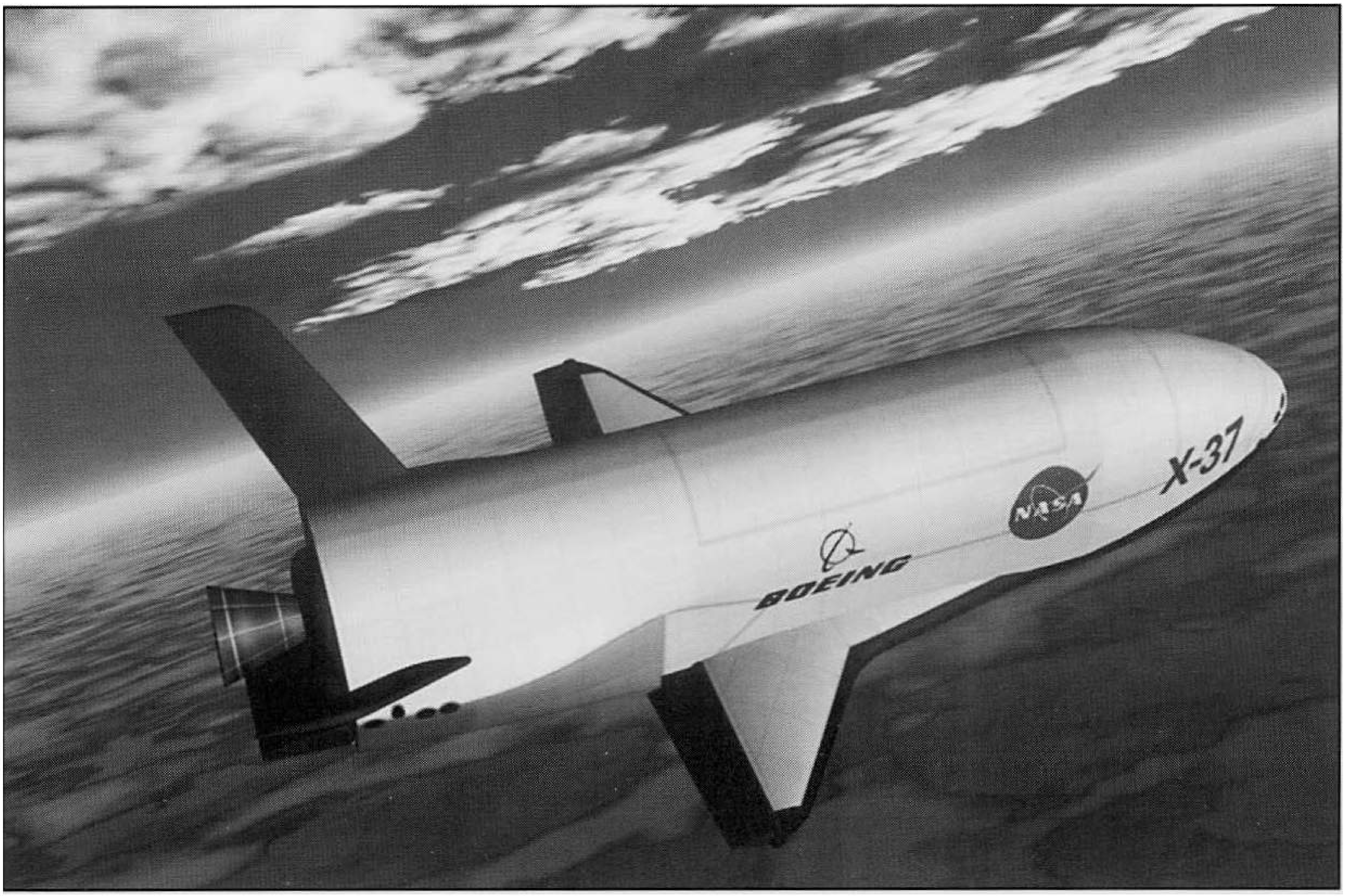
**Above, another view of Darryl in the cockpit. The October 1976 attempt was unofficially clocked at 1,010 mph. An October 1977 attempt was made necessary due to a timing camera malfunction. Below, wing tip extensions and lengthened nose from the NF-104A are evident in this classic photo. (via Tony Landis)**



# RESURRECTION OF THE ROCKETDYNE/BOEING AR2-3 ROCKET ENGINE



The NASA/Boeing X-37 Future X Space Maneuvering Vehicle shown here is being considered as a candidate for an upgraded version of the '50/'60 era AR2-3 rocket engine used in the NF-104A Aerospace Trainers. (NASA via Tony Landis)



# NF-104A AIRCRAFT SPECIFICATIONS

### WING

| | |
|---|---|
| Area | 212.8sqft |
| Aspect Ratio | 3.13 |
| Taper Ratio | 2.65 |
| Sweepback at 25% Chord | 18.1° |
| Dihedral | -10° |
| Incidence, Root & Tip | 0° |
| Airfoil Mod B1-Convex | 3.36% thick |
| Root Chord | 155.82 in. |
| Tip Chord | 41.5 in. |
| MAC at 60.8 in. from $C_L$ | 111 in. |

### AILERON

| | |
|---|---|
| Area -Total | 9.2sqft |
| Max Deflection | 45° |

### LANDING FLAPS

| | |
|---|---|
| Area - Total | 22.7sqft |
| Max Deflection | 30° |

### HORIZONTAL STABILIZER

| | | |
|---|---|---|
| Area | | 48.2sqft |
| Sweepback at 25% Chord | | 10.1° |
| Aspect Ratio | | 2.95 |
| Dihedral | | 0° |
| Airfoil Mod B-1-Convex, | Root | 4.93% thick |
| | Tip | 2.61% thick |
| Root Chord | | 74.0 in. |
| Tip Chord | | 23.0 in. |
| MAC at 25% Chord from $C_L$ | | 52.97 in. |
| Travel - LE | UP | 5° |
| | DOWN | 17° |

### DORSAL FIN AND RUDDER

| | | |
|---|---|---|
| Area - Total | | 41.9sqft |
| Rudder - Area | | 4.2sqft |
| Travel | | +/-20° |
| Sweepback at 25% Chord | | 32.2° |
| Airfoil Mod B1-Convex, | Root | 3.43% thick |
| | Tip | 4.04% thick |
| Root Chord at WL 138 | | 139.2 in. |
| Tip Chord at WL 203.5 | | 50.33 in. |
| MACat WL 162.6 | | 102.33 in. |
| Aspect Ratio | | 0.68 |

### SPEED BRAKE

| | |
|---|---|
| Area - Total | 8.25sqft |
| Travel | 52° |

| | |
|---|---|
| **FUSELAGE FRONTAL AREA** | 25sqft |

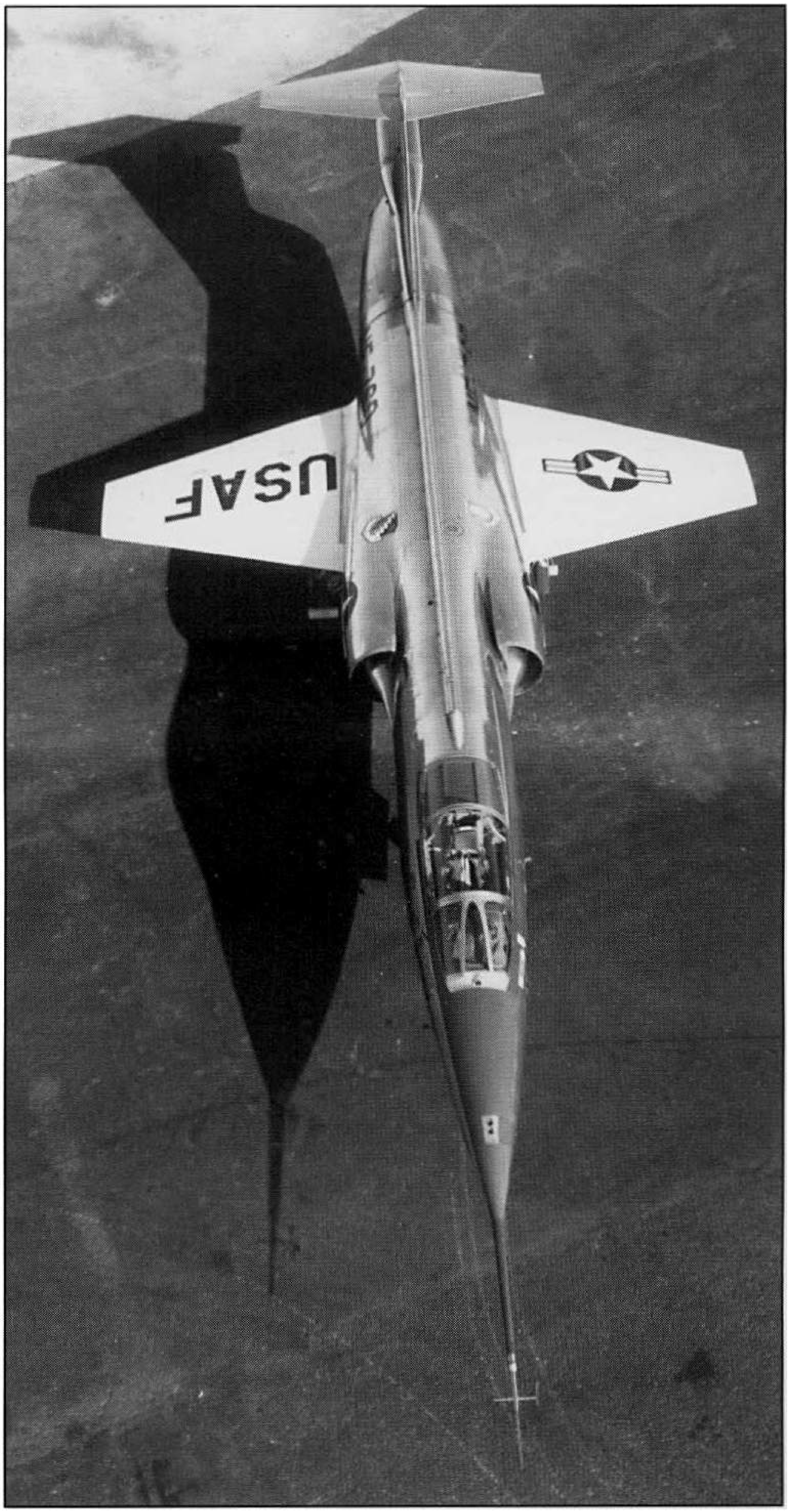
### VENTRAL FIN

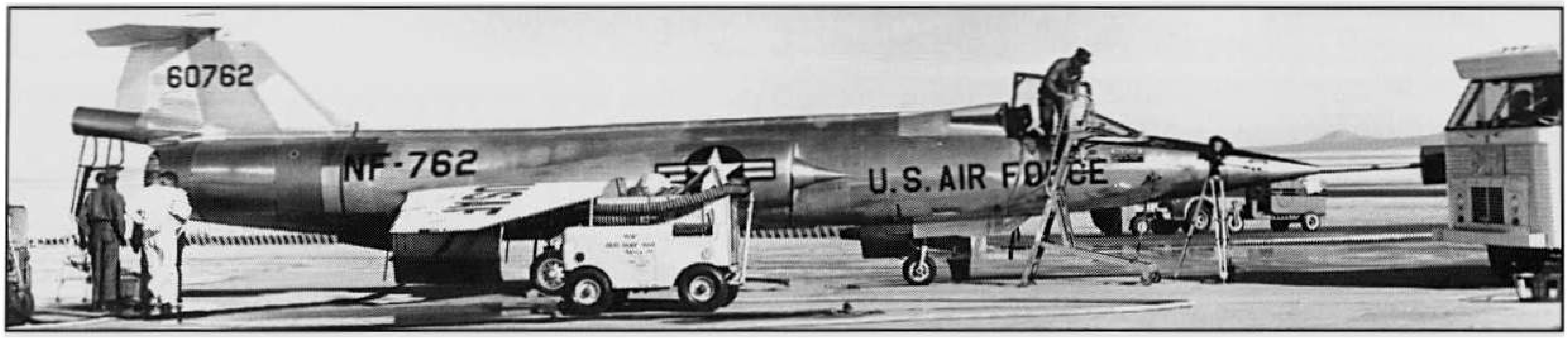
| | |
|---|---|
| Area | 5.9sqft |
| Length | 7.79 ft |
| Depth | 1.31 ft |
| Airfoil - Parabolic | 2.5% thick |

### WEIGHTS

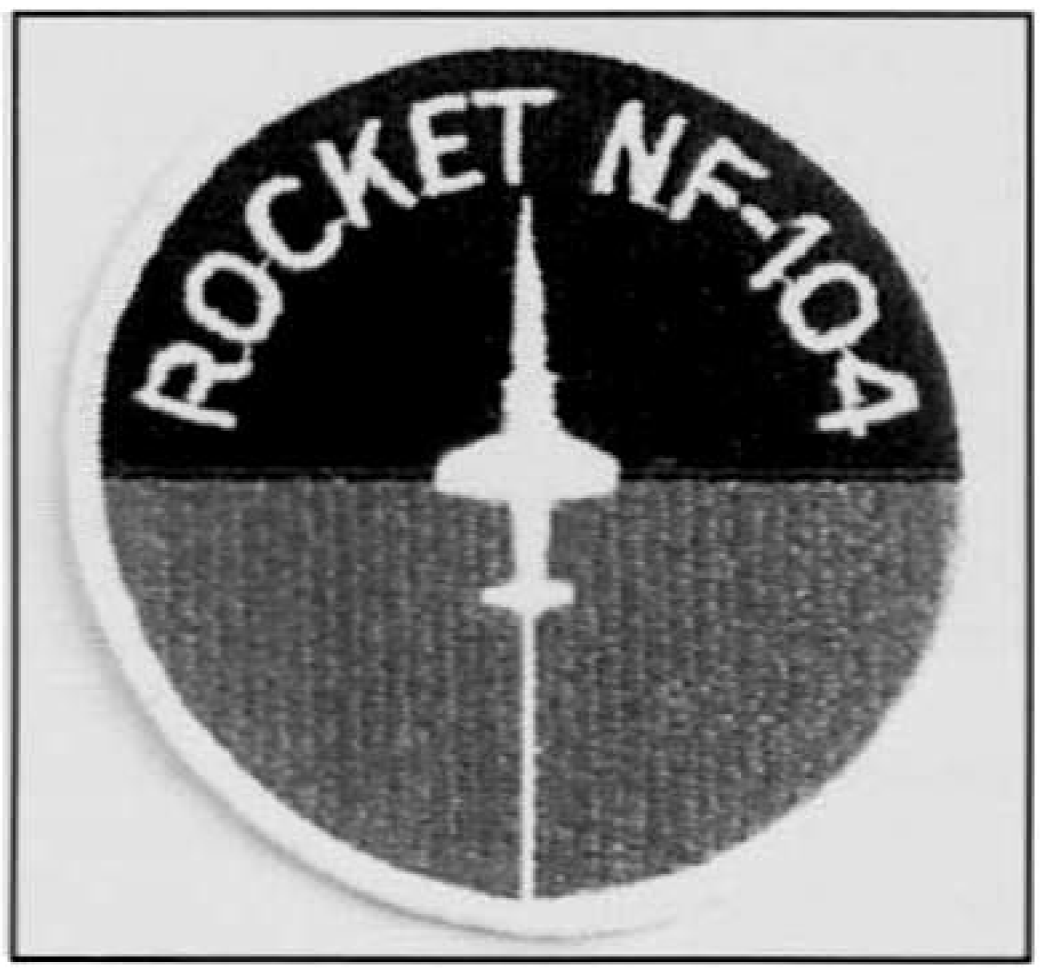
| | |
|---|---|
| Empty | 13,500 lbs |
| Fuel - JP4 | 4,960 lbs |
| Oxidizer - Rocket | 2,360 lbs |
| Monopropellant - Reaction | 150 lbs |
| Useful Load | 7,900 lbs |
| Design Gross | 21,400 lbs |

**Below, '760 from above. Note the spine fairing which was extended down both sides of the fin base to house the AR2-3 rocket controls and plumbing. Also note the unique nose boom and the two RCS ports in the forward nose cone.**

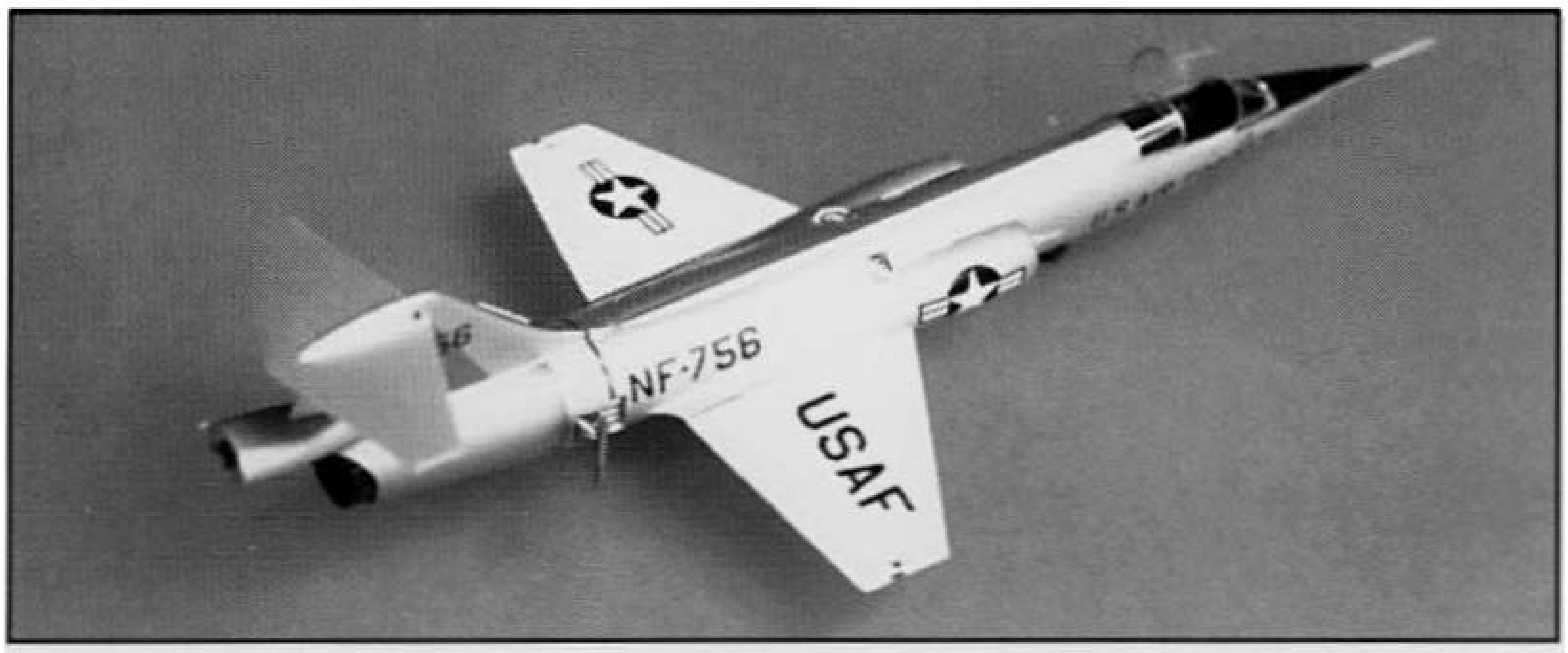


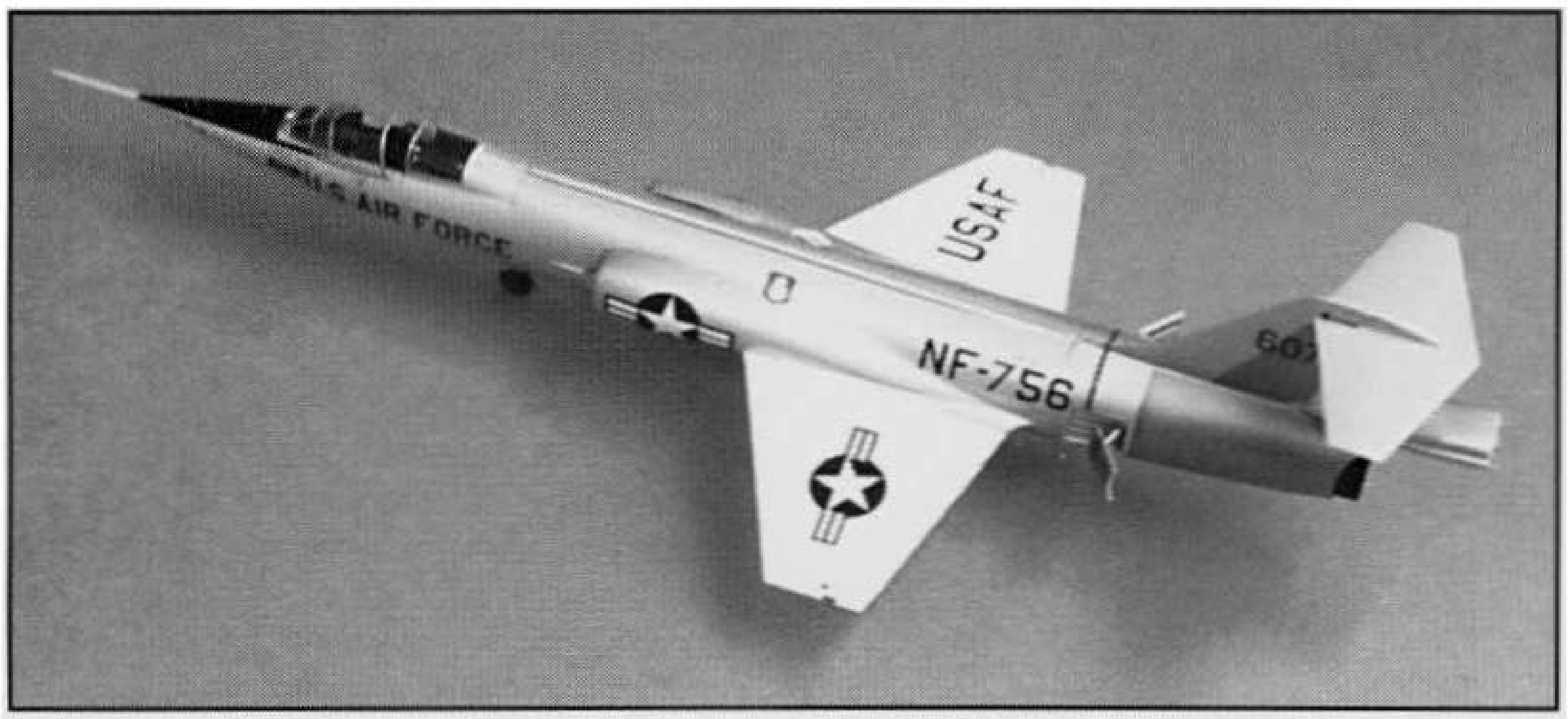


**Above, '762 only had complete markings with NF fuselage code for about a month prior to its loss. (via T. Landis) At left, '60s group flightline photo of the aircraft assigned to Edwards, including the NF-104A. (via T. Landis)**



## FOX 3 STUDIOS 1/48 SCALE NF-104A CONVERSION KIT





Gerald Asher of FOX 3 Studios at 6837 Northpark Drive, Fort Worth, Texas 76180-2669, provided us with these test shot photos of his soon-to-be released NF-104A conversion kit. For more information, send a SASE to FOX 3 studios for a kit listing and a current price list.

The kit is designed to be used with the Monogram kit, and will be a mixed media conversion kit. Resin is planned for the wing tips, intake shock cones, nose cone, and rocket engine fairing. Metal tubing will be used for the instrument boom and optional gaseous nitrogen purge system dump mast. The conversion kit will also include decals for all the NF-104As.

The test shot model does not include the correct instrument test boom, or the extended spine fairing that wraps around both sides of the vertical fin and houses the rocket motor controls and plumbing.

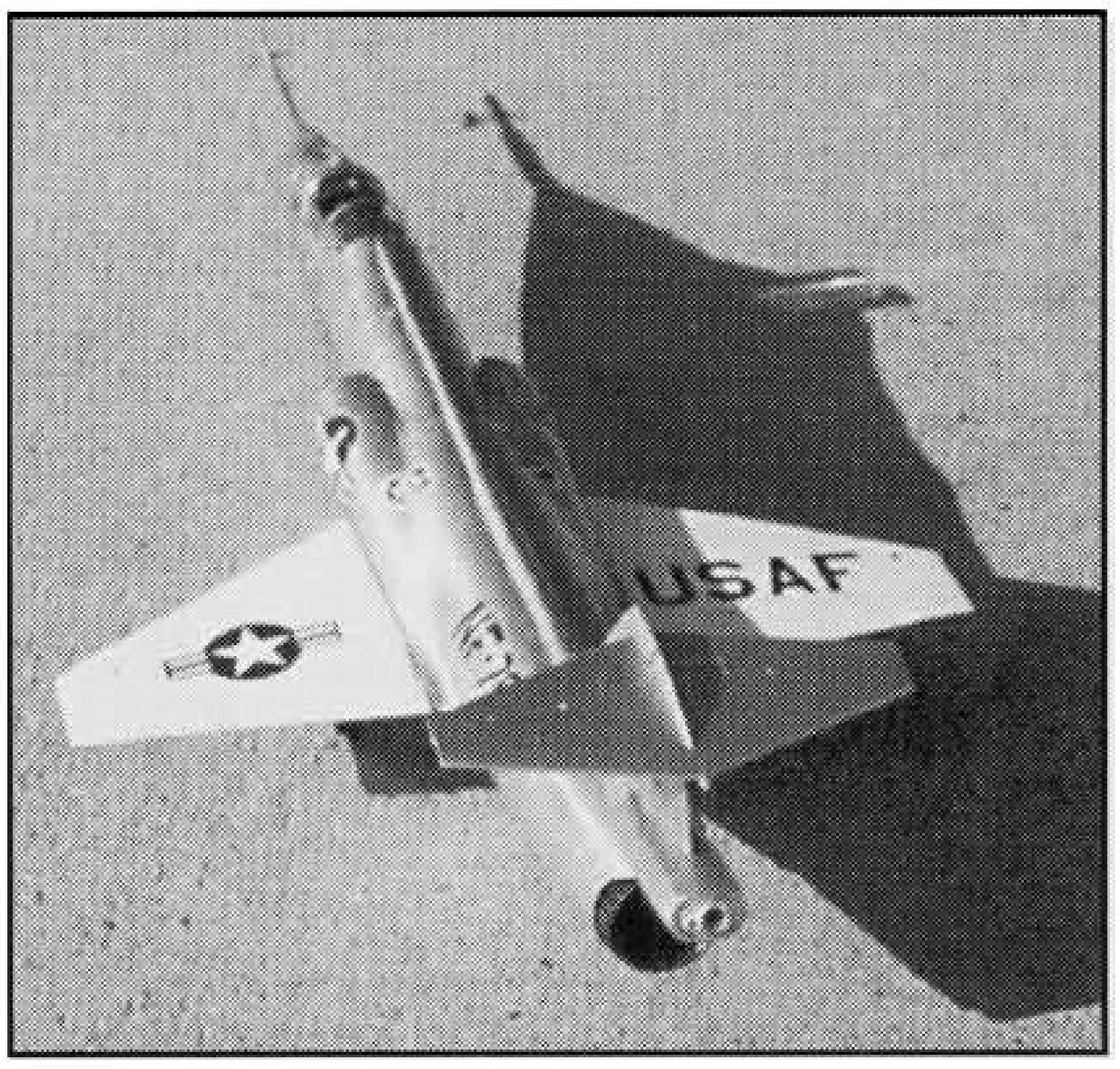
# TWELVE SQUARED 1/72 NF-104A CONVERSION KIT

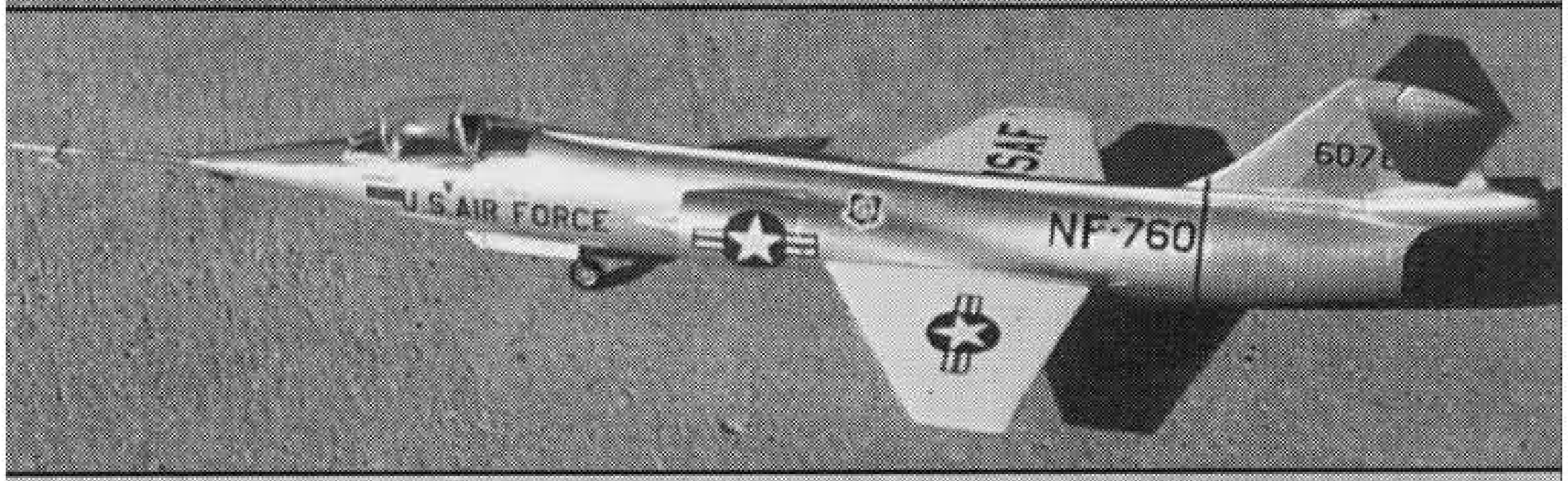
The model featured here was built by Steve Ginter with a test shot provided by Twelve Squared. For a current product list of Twelve Squared kits and current prices, send a SASE to Twelve Squared at PO Box 21567, Eagan, MN 55121.

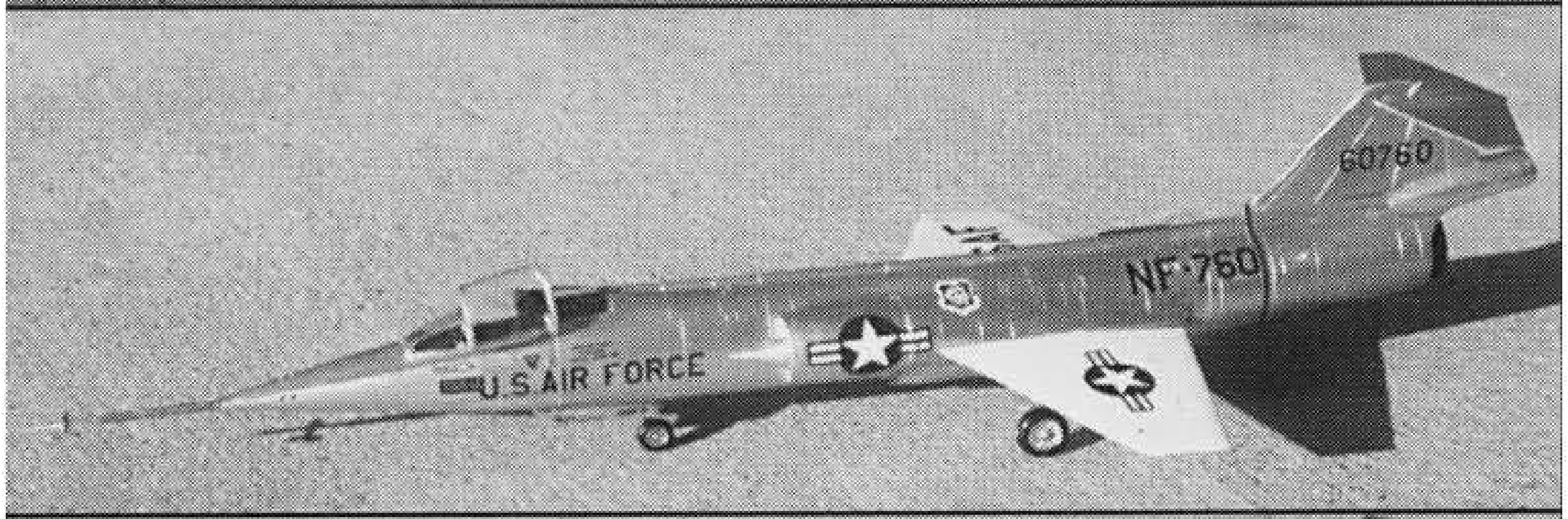
The conversion kit is designed around the excellent Hasegawa series of F-104 kits. The best kit for this purpose that is currently available is kit #02817, which depicts an F-104S/F-104G of the Italian Air Force. What makes this kit so good is that it has the F-104G tail, which must be used for the NF-104A, and the numerous early F-104A parts needed for the kit. These include the early style ejection seat, intakes, and short afterburner exhaust cone.

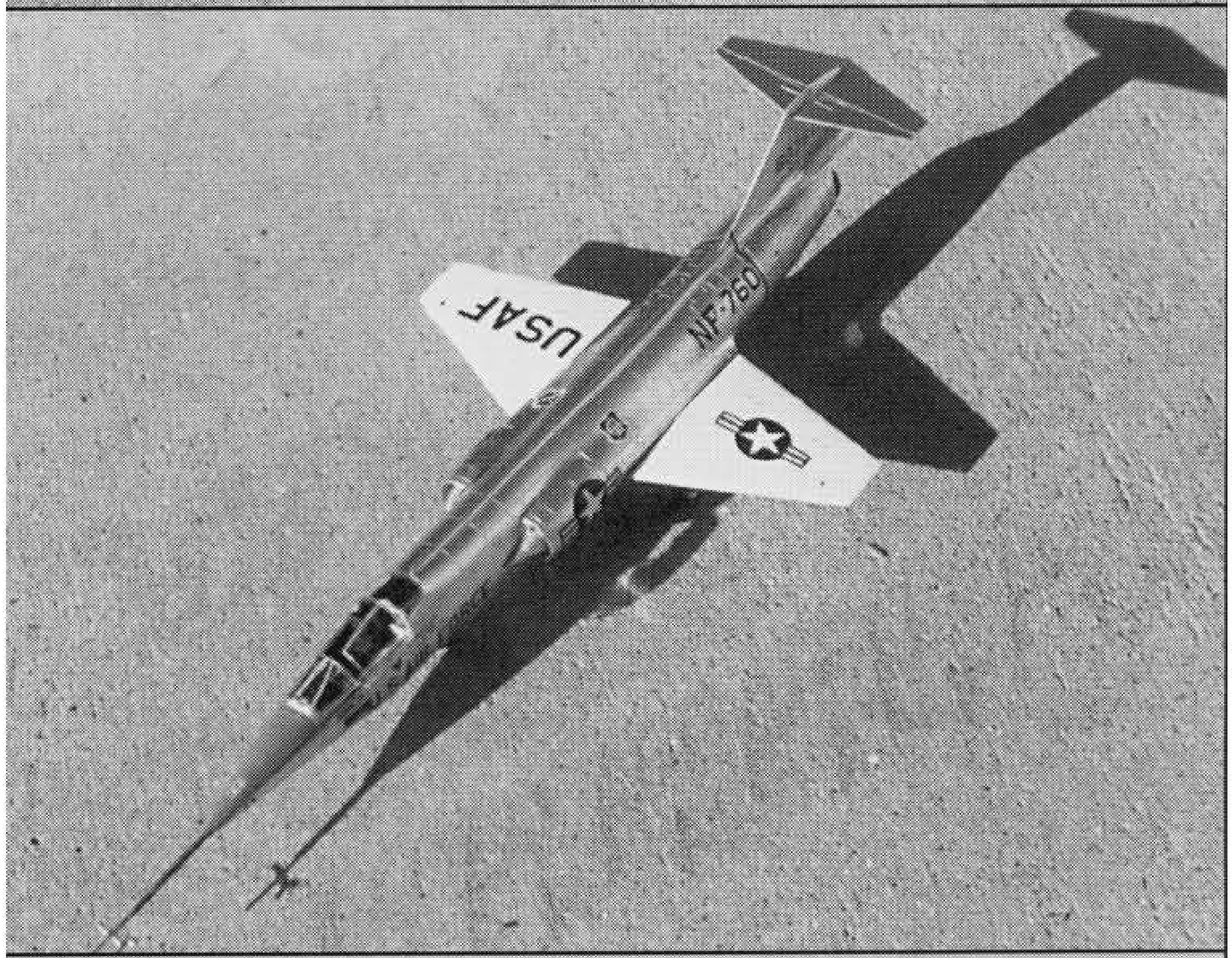
The kit will include a set of complete wings, as the 104's wings in 1/72 scale are too thin to easily add extensions to them. The mixed media kit will also include a new nose cone, left and right rocket engine fairing halves, exact fitting replacements for the intake spikes, an accurate nose instrument boom, and an accurately molded rocket engine face plate. Still in development is the spine fairing extension for the rocket engine controls and plumbing.

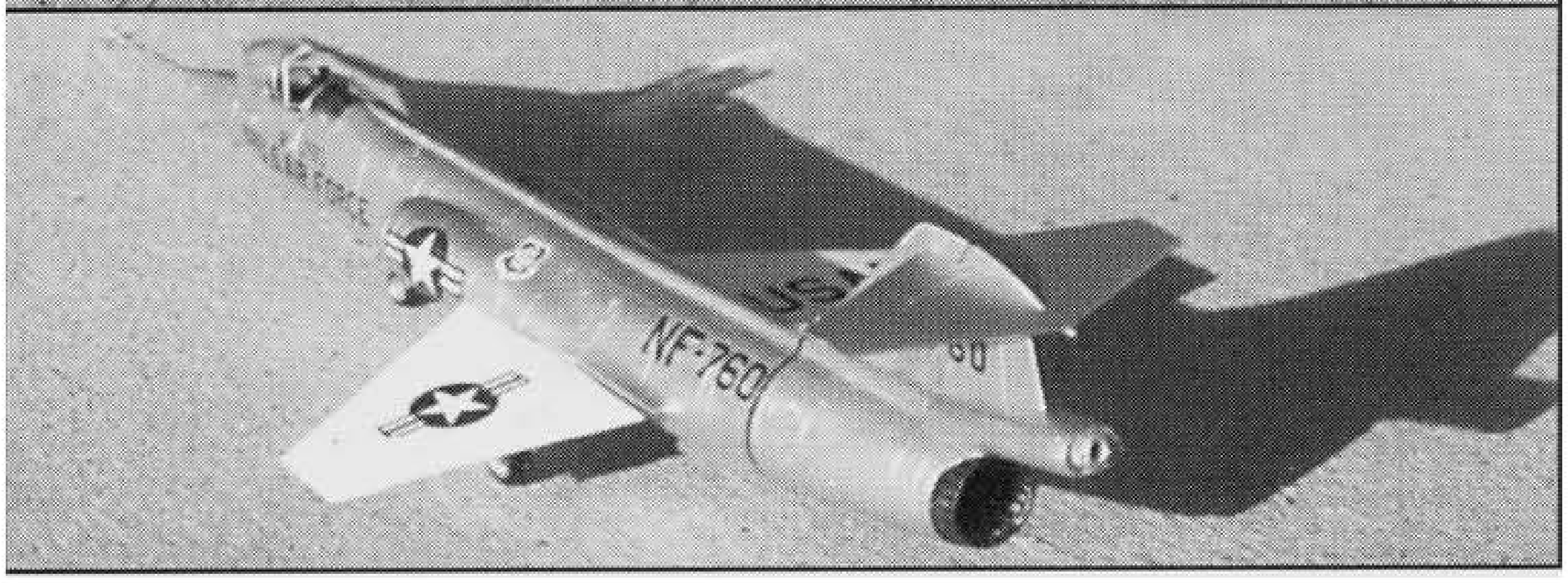
The fit of these test parts was perfect. The test boom was finely detailed and the rocket motor face plate was extremely accurate. No putty was needed to blend the aftermarket parts with the kit's parts. Scratch-building the spine fairing extension was the only difficult part. The production kits will include parts for the spine extension.

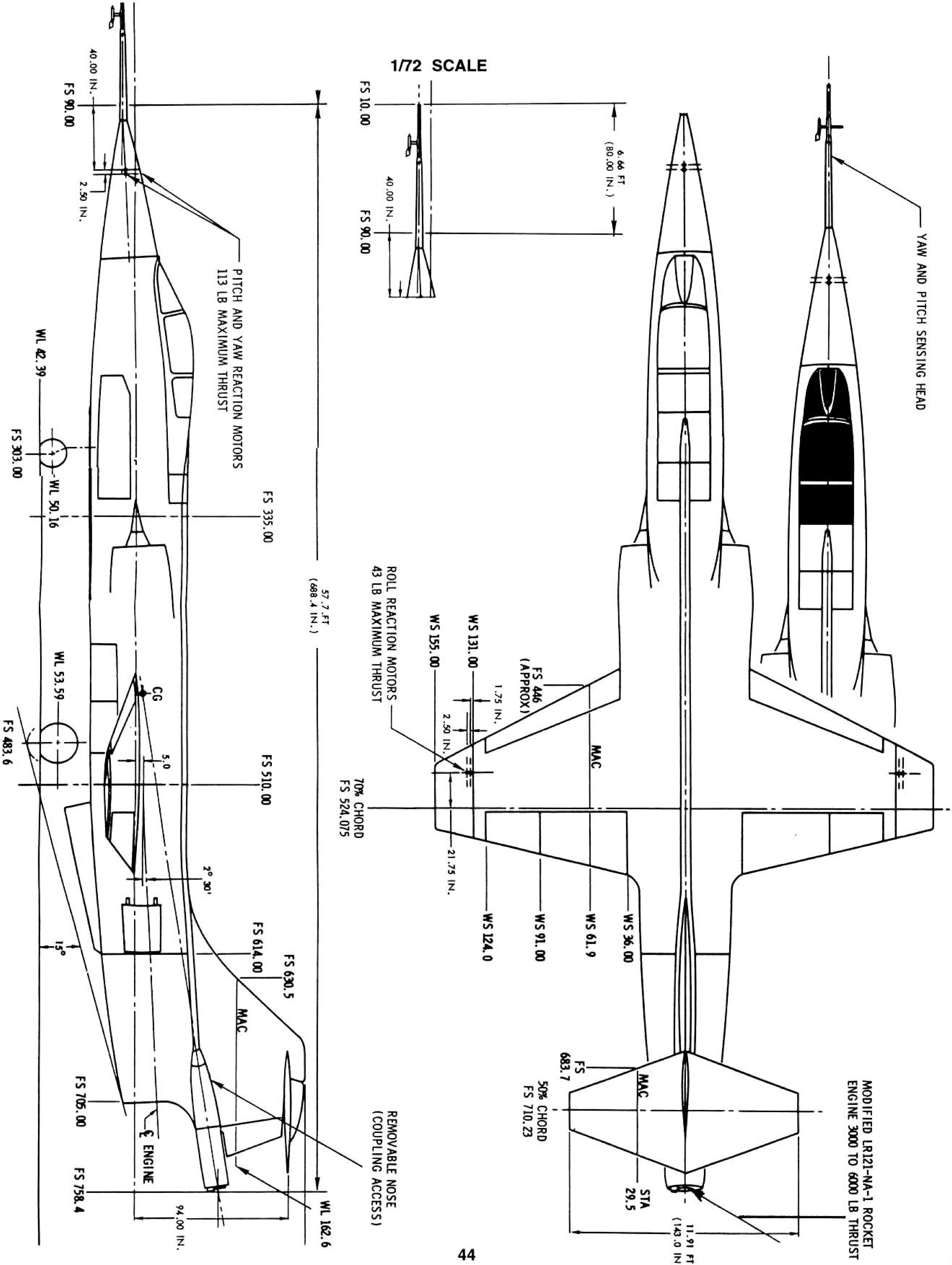


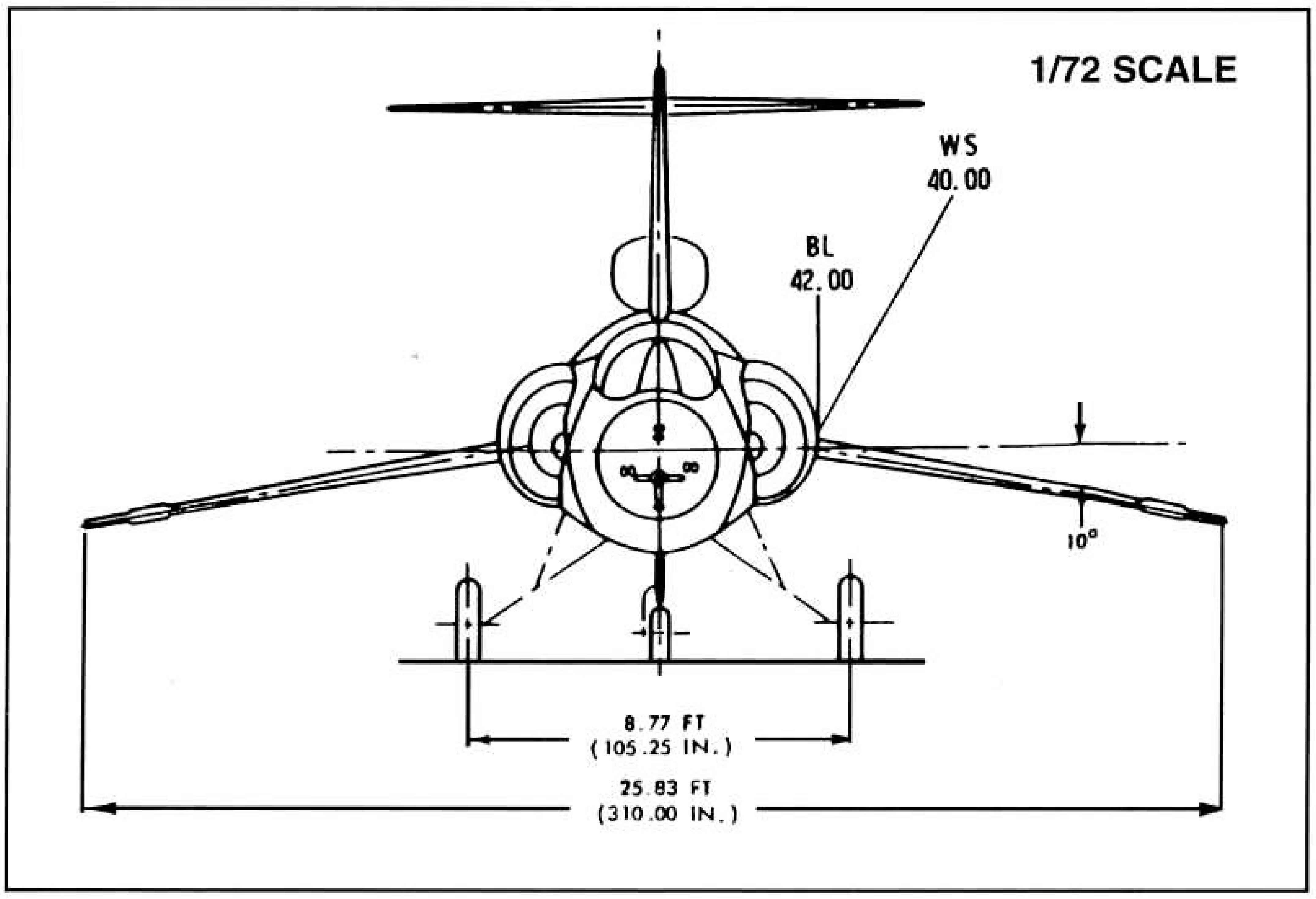









1/72 SCALE
FS 10.00
FS 90.00
40.00 IN.
6.66 FT
(80.00 IN.)
YAW AND PITCH SENSING HEAD
FS 90.00
40.00 IN.
2.50 IN.
PITCH AND YAW REACTION MOTORS
113 LB MAXIMUM THRUST
WL 42.39
FS 303.00
WL 50.16
FS 335.00
57.7 FT
(688.4 IN.)
WL 53.59
CG
FS 483.6
5.0
FS 510.00
2° 30'
15°
FS 614.00
FS 630.5
MAC
FS 705.00
℄ ENGINE
FS 758.4
94.00 IN.
WL 162.6
REMOVABLE NOSE
(COUPLING ACCESS)
ROLL REACTION MOTORS
43 LB MAXIMUM THRUST
WS 131.00
WS 155.00
FS 446
(APPROX)
1.75 IN.
2.50 IN.
MAC
70% CHORD
FS 524.075
21.75 IN.
WS 124.0
WS 91.00
WS 61.9
WS 36.00
FS
683.7
MAC
50% CHORD
FS 710.23
STA
29.5
11.91 FT
(143.0 IN.)
MODIFIED LR121-NA-1 ROCKET
ENGINE 3000 TO 6000 LB THRUST



**BACK COVER**

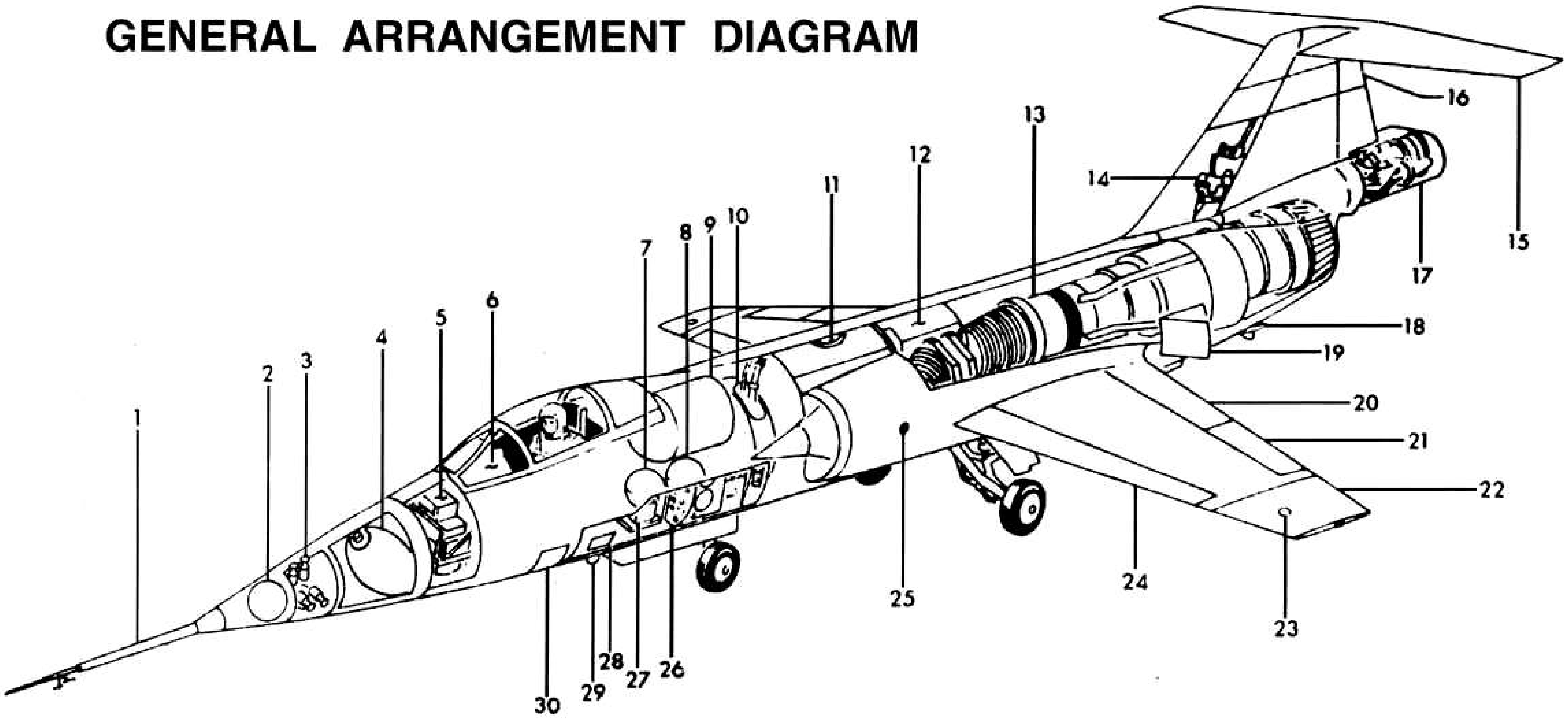
Top, NF-104A 60-760 in flight over Edwards AFB. (via Craig Kaston)

Upper middle, 760 with USAF Test Pilot School insignia on the upper fuselage above and aft of the engine intake. (via Tony Landis)

Lower Middle, NF-104A 60-756 on the ramp after fueling, stands ready for a student pilot. The water on the ramp is a typical precaution when dealing with Hydrogen Peroxide. A fire hose is always on hand to neutralize any spillage. (via Tony Landis)

Bottom, test stand firing of the RCS motors. The left hand yaw motor has just been shut off and the smoke is clearing. (via Tony Landis)

## GENERAL ARRANGEMENT DIAGRAM



1.) Yaps Head Boom
2.) RCS Pressurization $GN_2$ Tank
3.) RCS Pitch and Yaw Motors (Eight)
4.) RCS $H_20_2$ Tank
5.) Oscillograph
6.) Electrically Heated Windscreen
7.) Cockpit Pressurization $GN_2$ Tank
8.) $H_20_2$ Pressurization $GN_2$ Tank
9.) Forward $H_20_2$ Tank
10.) Aft $H_20_2$ Tank
11.) Forward Main JP-4 Fuel Tank
12.) Aft Main JP-4 Fuel Tank
13.) J79-GE-3B Turbojet Engine with Afterburner
14.) Horizontal Stabilizer Power Control Assembly
15.) Controllable Horizontal Stabilizer
16.) Rudder
17.) Modified LP 121-NA-1 Rocket Engine
18.) Drag Chute Door
19.) Speed Brake
20.) Trailing Edge Flap
21.) Aileron
22.) Wing Tip Extension
23.) RCS Roll Motor (Two Each Wing Tip)
24.) Leading Edge Flap
25.) Navigation Lights (Six)
26.) Automatic Observer (AO) Panel
27.) Thirty-Four-Amp-Per-Hour Battery
28.) UHF Receiver / Transmitter
29.) APW-11 Transmitter Antenna
30.) UHF Antenna

60760
U.S. AIR FORCE
NF-760

60760
U.S. AIR FORCE
NF-760

NF-756
U.S. AIR FORCE
SAFETY SHOWER

NASA
52961
U.S. AIR FORCE
FG-961